Scattering Theory. By John R. Taylor. John Wiley and Sons, Inc., New York (1972). 477 pp. $14.95.

In the Preface to *Scattering Theory*, the author, John R. Taylor, states, "This book is intended for any student of physics who wants a thorough grounding in the theory of nonrelativistic scattering. It is designed for a reader who is already familiar with . . . quantum mechanics (as . . . the first year graduate course) . . . . The book is . . . less useful as a reference for the active researcher."

In my opinion, the author has served his purpose admirably well. The book is extremely clearly written and should be easily understood by any graduate student of either physics or engineering, so long as the requisite quantum course has been studied. Taylor's approach is also sound pedagogically, in that he first (in Chaps. 1 through 15) develops all the formulas for single-channel (i.e., elastic) scattering. In Chaps. 16 through 22, he extends the formalism to the multichannel case, but by then the basic principles should be well understood by the reader and the general case is more or less a matter of computational detail.

The author takes the "modern" approach, which is to develop scattering theory initially in the "time dependent" formalism, by using the Møller wave operators which convert the asymptotic "in" and "out" states to the actual orbits of the system. The *S* matrix is then introduced, as are the on- and off-shell *T* matrices, in terms of which expressions for the cross section is derived. The connection between scattering by a fixed potential and two-body scattering is explained, and the relationship between the momentum (or "experimental" basis) and the angular momentum (or "partial wave") basis is derived. Scattering between particles with spin is treated, and the author even derives the helicity representation that is so important in relativistic problems.

The next step is to express stationary-state scattering theory, through Green's function techniques, the Born approximation, and the Lippman-Schwinger equation, and derive its connection with the time-dependent formalism. Then a number of very special topics are considered, including partial wave amplitudes and Jost functions,[a] and analytic properties when the energy or momentum are allowed to take on complex values. Bound states and resonances are described in terms of poles of the *S* matrix (or, if you prefer, zeroes of the Jost function) and dispersion relations introduced, including the Mandelstam double-dispersion representation, with subtractions. Even Regge poles make the grade, and the author attempts to clarify to the reader how these concepts have been applied in particle physics.

[a]Jost functions have recently been introduced into transport theory by K. M. Case (to be published); that is another reason why nuclear engineers might study this book.

From this summary, one can see that most of the basic ideas important in modern physics are included in the book, in a particularly simple context, i.e., nonrelativistic scattering theory. To the reader who wants to understand what the particle physicists are really doing, this book should be invaluable. For the nuclear engineer who wants to understand the bases of the calculations and measurements that provide his cross-section data, the book should be equally invaluable. For the technically inclined reader, who feels like spending several pleasant evenings studying a clear exposition of what's up in modern physics, the book should be a pleasure!

To end with one slightly critical note, I do feel that perhaps a single chapter, at least sketching out how the various concepts are applied to the relativistic case, would have been valuable. However, there are ample references, and the interested reader can and should consult them.

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About the Reviewer: Paul Zweifel is experiencing a long and varied career in nuclear science and technology. His present association as University professor of physics and nuclear engineering at the Virginia Polytechnic Institute and State University and his pedagogical experience at the University of Michigan and at Middle East Technical University qualify him highly as the reviewer of this text on scattering. Dr. Zweifel did his academic studies at Carnegie Institute of Technology and Duke University.

The Invariant Imbedding Theory of Nuclear Transport. By J. O. Mingle. American Elsevier Publishing Company, Inc., New York (1973). 131 pp. $11.50.

If the reactor physicist or shield designer has wanted to know the impact invariant imbedding could have on his work, the situation has been either feast or famine. Until recently, there was no text devoted to this area. Now within the last year, two books on the subject, both rather short monographs, have been published. The first of these, *Application of Invariant Imbedding to Reactor Physics*, by A. Shimizu and K. Aoki, appeared in 1972 and was reviewed in this journal (May 1973). The book we shall discuss here is *The Invariant Imbedding Theory of Nuclear Transport*, written by John Mingle, currently the director of the Institute for Computational Research in Engineering and a professor of nuclear engineering at Kansas State University.

Dr. Mingle is particularly well suited to have authored a book on invariant imbedding. He was introduced to the subject by Richard Bellman, an early proponent of the application of invariance principles to nuclear transport and the one who coined the term "invariant imbedding." After a brief period of working with Bellman at the University of Southern California, Dr. Mingle returned to Kansas State and in the next few years he and his students published several papers concerned with formulating and solving the equations of invariant imbedding.

The easy part of any review is to summarize the contents of the book, and we shall begin with this. After a very brief "setting the scene" in Chap. 1, Chap. 2 reviews the basic invariant imbedding concepts. This chapter is built around the classic rod example, where monoenergetic particles are constrained to move along a line. Otherwise, all aspects of real-world particle transport are present, i.e., absorption, scattering, and fission. The familiar kinetic or transport equation approach is presented first and results in two linear first-order (or equivalently, one second-order) differential equations for the partial currents. Reflection and transmission coefficients are then defined in terms of the partial currents, and simple substitution into the kinetic equations yields the equations of invariant imbedding. The equation for the reflection function is a first-order differential equation, but it is nonlinear, containing the square of the function. The equation for the transmission function is also first order, and although it involves the reflection function, it is linear. This is the only example found in the book of the strictly mathematical Ricatti-type transformation, i.e., converting a second-order linear equation to a first-order nonlinear equation. The remainder of the book uses particle-counting techniques to derive the equations of invariant imbedding for more realistic transport problems. This approach is introduced in Chap. 2 by rederiving the equations for the rod example by particle-counting techniques.

This introduction in Chap. 2 serves to point out the major advantage and disadvantage of the invariant imbedding technique as contrasted with the usual transport equation approach. The advantage is a powerful one from a computing point of view; namely, the transport equation approach which involves boundary conditions at both surfaces of the system is replaced by the invariant imbedding equations which involve a boundary condition at only one surface. Thus, from a mathematical viewpoint, a boundary value problem has been converted to an initial value problem, and numerically an initial value equation is much easier to integrate. The fact that the equations of invariant imbedding are nonlinear is not a serious problem in any numerical solution. The major conceptual disadvantage to the invariant imbedding approach is that it only gives information concerning the reflection from and the transmission through a system; it does not yield directly an internal flux distribution. A practical disadvantage is that the method to date has only been developed for one-dimensional geometry.

Returning now to the book under review, Chaps. 3 through 7 apply the particle-counting technique to several energy-dependent, slab-geometry transport problems, namely the standard-albedo, transmission, and escape-probability problems. The energy variable is treated in both the continuous and multigroup form in the formulations. Some discussion of calculational methods is given, including a brief review of Gaussian and Radau quadrature methods for angular integration. Chapter 8 considers the reduction of the energy-dependent equations of invariant imbedding to the special case of monoenergetic transport. Further reduction is made to discuss successively the blackness coefficient, escape-probability, criticality, multiple-slab, disadvantage-factor, and semi-infinite medium problems. Throughout this chapter, numerical comparisons with other published results are given. Chapter 9 considers the invariant imbedding formulation of multiparticle transport, such as coupled neutron-gamma problems. Not much is really added here, other than a proliferation of superscripts. The same general comment holds for Chap. 10, which considers the special case of photon transport. No additional understanding of invariant imbedding is found in this chapter.

Chapter 11, the last section in the book aside from a short appendix on Runge-Kutta techniques, deals with invariant imbedding in curved geometry, with particular emphasis on spherical systems. This chapter is rather interesting in view of the results it reports. After a rather tortuous derivation of the reflection equation, the author indicates that this equation does not give the correct unscattered contribution (those particles which pass through the sphere uncollided) to the reflection coefficient for a solid, homogeneous sphere. A second equation is then given which does correctly treat the unscattered component because this component was separated out in the derivation, using the first-collision particles as an internal source in deriving the invariant imbedding equation for the scattered particles. However, there is no evidence presented that the scattered component predicted by either equation is correct. The author concludes this chapter with the observation that "the application of invariant imbedding theory to transport problems of curved geometry remains a 'wide open' field." This would seem to be an understatement.

Finally, we come to the crux of any book review. Is this a good book? I think in the present case this depends a great deal on the personal taste of the reader. The book contains a great deal of algebraic detail that contributes little to an underlying understanding of invariant imbedding. On the other hand, for students and other readers introduced to this subject for the first time, algebraic detail takes some of the mystery out of the subject. One can follow step-by-step from the particle-counting concept to the final, rather involved, equations. The book is clearly intended for students in that each chapter is followed by a set of exercises. Throughout the book, the author stresses he has employed the particle-counting, rather than the mathematical-transformation, approach to the derivation of the equations of invariant imbedding. I think the book could have been improved somewhat if the desire of the author to stress the physical rather than the mathematical had been carried further. There are numerous instances in the text where results could have been made more palatable with a few words of explanation. For example, in the rod problem the author shows algebraically that no matter how large the mean number of secondaries per collision, a critical rod is not possible if the angular distribution of these fission particles is entirely in the forward direction. What is the physical basis of this result?

Let me end by addressing the point alluded to in the first sentence of this review. My impression of invariant imbedding, reinforced by reading this book, is that as a practical computational tool it is at present restricted to one-dimensional (primarily slab) steady-state problems. Many other techniques are already in use to handle this class of problems, and with present-day computers the cost of such calculations is minimal. People have built up a reservoir of experience in these other techniques, and since cost and computer storage are not a restrictive factor for these one-dimensional problems, there is very little incentive to start using invariant imbedding techniques on a large scale. A possible exception to this is in deep-penetration calculations, such as in shielding problems, where the large attenuations experienced can lead to numerical difficulties with more conventional techniques based on the transport equation.

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About the Reviewer: Gerald Pomraning has been a staff member of the Theoretical Physics Group at Science Applications, Inc., since 1969, following seven years of reactor physics work at General Electric and Gulf General Atomic. Dr. Pomraning received his PhD in nuclear engineering from the Massachusetts Institute of Technology in 1962. His current research interests are in radiative transfer and radiation hydrodynamics, with a continuing interest in neutron transport.

Environmental Radioactivity. By Merrill Eisenbud. 2nd ed. Academic Press, New York (1973). 542 pp. $29.50.

The many persons who have made good use of *Environmental Radioactivity* by Merril Eisenbud (McGraw-Hill) as a valuable reference and source of information on many subjects will be happy to know that this text is now available in Second Edition. It not only is reproduced by a new publisher (Academic Press) but in many respects is a new test containing a new section (Peaceful Uses of Nuclear Explosives), many new subject areas, and a number of additional tables, graphs, drawings, photographs, equations, etc., which make it an essential addition to the library of scientists, engineers, college students, and even administrators, many of whom have found the first edition a frequent reference. This second edition, with its 25% increase in pages, is now the latest in an interdisciplinary monograph series of 14 texts on Environmental Sciences. Because of its brief treatment of such a great variety of subject areas ranging from natural background radiation, its effects on man and his environment, the transport of radioactive contaminants in the air, water, and soil, radiation protection standards, the nuclear energy industry including mining, fuel fabrication and reprocessing, reactor operations and waste disposal, fallout, radiation accidents, peaceful applications of nuclear energy, and environmental surveillance, it is an almost essential first reference for one checking numbers, dates, mechanisms, working equations, reactor incidents, regulations, etc. However, by definition it would be of no value to the specialist such as the cosmic-ray physicist seeking information in his subject area, the meteorologist seeking information on micrometrology, or the nuclear engineer wishing information, for example, on the high-temperature gas-cooled breeder reactor. Each of these specialists, however, would find most useful information on a score of subject areas and especially as they relate to the subject of environmental radioactive contamination.

There are so many outstandingly good features of this book that one has to look hard to find things with which he disagrees or to which he objects. This reviewer, however, was given the feeling at times that the writer avoided pointing out some of the mistakes of the AEC and that he gave too little effort in relating the evidence of damage from low levels of radiation exposure and in making a strong case for the linear hypothesis relating accumulated radiation dose to radiation damage. For example, the apparent disagreements between the magnitude of increase in malignancies among children who received *in utero* exposure from diagnostic exposure of the mothers, as found in Alice Stewart's Oxford studies, and among the Japanese children who had received *in utero* exposure when their mothers survived the atomic bombings of Hiroshima and Nagasaki were pointed out, but the important logical explanations that readily account for the differences were not given. The discussion on internal dose is factual and clearly written, but will be out of date when viewed in terms of the concept that body burdens and MPC values must be treated at best as only secondary standards and that the only reliable index and the one being used in the new internal dose handbooks of the International Commission on Radiological Protection (which will be published in the Fall of 1974) is the permissible annual dose commitment. This corresponds to a dose to the critical body organ that is numerically equal to the maximum permissible annual dose following any pattern of intake of a radionuclide.

This reviewer found only a few "half truths" or partially incorrect statements in the text. For example, it is stated that tritium originates in *two* ways in reactor wastes. Actually, there are a number of reactions that account for this radioactive contaminant. Another example of a partially erroneous statement is that the risk of terrestrial and marine applications of isotopic power generators can be *eliminated* by massive design of the containment and by restricting the locations in which the units will be used. This sentence could be made correct by replacing the word *eliminated* by *made insignificant*. In another example, the parent of the neptunium series of radionuclides is given as ^{241}Pu, presumably because it occurs earlier in this chain. However, the convention is to choose the longest lived controlling radionuclide as the parent element in a chain. The other three series of radionuclides (^{238}U, ^{235}U, and ^{232}Th) also had many short-lived precursers which long since have disappeared, but we do not consider them as the parent radionuclides.

This reviewer found remarkably few errors in the publication. In particular, he would note that on page 188 the ^{14}C body content of the average man is given as 0.1 Ci instead of 0.1 μCi.

Some of the chapters, such as the one on "Food Chain from Soil to Man" and the one on "Natural Radioactivity," are outstandingly good and offer the reader a wealth of useful information. The bibliography containing about 900 references will be most helpful to the reader wishing more information. In general, Merril does an excellent job in consolidating a vast amount of information on environmental radioactivity.

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