



# Mathematical and Analytical Methods in the Physical Sciences

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The importance of mathematics in the study of problems arising from the real world, and the increasing success with which it has been used to model situations ranging from the purely deterministic to the stochastic, in all areas of today's Physical Sciences and Engineering, is well established. The purpose of the sets of volumes, the present one being the first in a planned series of sequential sets, is to make available authoritative, up to date, and self-contained accounts of some of the most important and useful of these analytical approaches and techniques. Each volume in each set will provide a detailed introduction to a specific subject area of current importance, and then goes beyond this by reviewing recent contributions, thereby serving as a valuable reference source. The progress in applicable mathematics has been brought about by the extension and development of many important analytical approaches and techniques, in areas both old and new, frequently aided by the use of computers without which the solution of realistic problems in modern Physical Sciences and Engineering would otherwise have been impossible. A case in point is the analytical technique of singular perturbation theory (Volume 3), which has a long history. In recent years it has been used in many different ways, and its importance has been enhanced by its having been used in various fields to derive sequences of asymptotic approximations, each with a higher order of accuracy than its predecessor. These approximations have, in turn, provided a better understanding of the subject and stimulated the development of new methods for the numerical solution of the higher order approximations. A typical example of this type is to be found in the general study of nonlinear wave propagation phenomena as typified by the study of water waves. Elsewhere, as with the identification and emergence of the study of inverse problems (volumes 1 and 2), new analytical approaches have stimulated the development of numerical techniques for the solution of this major class of problems. Such work divides naturally into two parts, the first being the identification and formulation of inverse problems, the theory of ill-posed problems and the class of one-dimensional inverse problems, and the second being the study and theory of multidimensional inverse problems. Volume 1: Inverse Problems 1 Volume 2: Inverse Problems 2 Alexander G. Ramm, Author These volumes present the theory of inverse spectral and scattering problems and of many other inverse problems for differential equations in an essentially self-contained way. Highlights of these volumes include novel presentation of the classical theories (Gel'fand-Levitan's and Marchenko's), analysis of the invertibility of the inversion steps in these theories, study of some new inverse problems in one- and multi-dimensional cases; I-function and applications to classical and new inverse scattering and spectral problems, study of inverse problems with "incomplete data", study of some new inverse problems for parabolic and hyperbolic equations, discussion of some non-overdetermined inverse problems, a study of inverse problems arising in the theory of ground-penetrating radars, development of DSM (dynamical systems method) for solving ill-posed nonlinear operator equations, comparison of the Ramm's inversion method for solving fixed-energy inverse scattering problem with the method based on the Dirichlet-to-Neumann map, derivation of the range of applicability and error estimates for Born's inversion, a study of some integral geometry problems, including tomography, inversion formulas for the spherical means, proof of the invertibility of the steps in the Gel'fand-Levitan and Marchenko inversion procedures, derivation of the inversion formulas and stability estimates for the multidimensional inverse scattering problems with fixed-energy noisy discrete data, new uniqueness and stability results in obstacle inverse scattering, formulation and a solution of an inverse problem of radiomeasurements, and methods for finding small inhomogeneities from surface scattering data. Several open problems are formulated. Volume 3: Singular Perturbation Theory: Essentials and Applications Robin S. Johnson, Author The theory of singular perturbations has been with us, in one form or another, for a little over a century (although the term `singular

perturbation' dates from the 1940s). The subject, and the techniques associated with it, have evolved over this period as a response to the need to find approximate solutions (in an analytical form) to complex problems. Typically, such problems are expressed in terms of differential equations which contain at least one small parameter, and they can arise in many fields: fluid mechanics, particle physics and combustion processes, to name but three. The essential hallmark of a singular perturbation problem is that a simple and straightforward approximation (based on the smallness of the parameter) does not give an accurate solution throughout the domain of that solution. Perforce, this leads to different approximations being valid in different parts of the domain (usually requiring a `scaling' of the variables with respect to the parameter). This in turn has led to the important concepts of breakdown, matching, and so on. This volume has been written in a form that should enable the relatively inexperienced (or new) worker in the field of singular perturbation theory to learn and apply all the essential ideas. To this end, the text has been designed as a learning tool.

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