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## For Whom Is This Book Written?

*Crow's Law: Do not think what you want to think until you know what you ought to know.*<sup>1</sup>

Linear algebra is a living, active branch of mathematical research which is central to almost all other areas of mathematics and which has important applications in all branches of the physical and social sciences and in engineering. However, in recent years the content of linear algebra courses required to complete an undergraduate degree in mathematics—and even more so in other areas—at all but the most dedicated universities, has been depleted to the extent that it falls far short of what is in fact needed for graduate study and research or for real-world application. This is true not only in the areas of theoretical work but also in the areas of computational matrix theory, which are becoming more and more important to the working researcher as personal computers become a common and powerful tool. Students are not only less able to formulate or even follow mathematical proofs, they are also less able to understand the underlying mathematics of the numerical algorithms they must use. The resulting knowledge gap has led to frustration and recrimination on the part of both students and faculty alike, with each silently—and sometimes not so silently—blaming the other for the resulting state of affairs. This book is written with the intention of bridging that gap. It was designed to be used in one or more of several possible ways:

- (1) As a self-study guide;
- (2) As a textbook for a course in advanced linear algebra, either at the upper-class undergraduate level or at the first-year graduate level; or
- (3) As a reference book.

It is also designed to be used to prepare for the linear algebra portion of prelim exams or Ph.D. qualifying exams.

This volume is self-contained to the extent that it does not assume any previous knowledge of formal linear algebra, though the reader is assumed to have been exposed, at least informally, to some basic ideas or techniques, such as matrix manipulation and the solution of a small system of linear equations. It does, however,

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<sup>1</sup>This law, attributed to John Crow of King's College, London, is quoted by R.V. Jones in his book *Most Secret War*, Wordsworth, 1998 (ISBN 978-1853266997).

assume a seriousness of purpose, considerable motivation, and modicum of mathematical sophistication on the part of the reader.

The theoretical constructions presented here are illustrated with a large number of examples taken from various areas of pure and applied mathematics. As in any area of mathematics, theory and concrete examples must go hand in hand and need to be studied together. As the German philosopher Immanuel Kant famously remarked, concepts without precepts are empty, whereas precepts without concepts are blind.

The book also contains a large number of exercises, many of which are quite challenging, which I have come across or thought up in over thirty years of teaching. Many of these exercises have appeared in print before, in such journals as *American Mathematical Monthly*, *College Mathematics Journal*, *Mathematical Gazette*, or *Mathematics Magazine*, in various mathematics competitions or circulated problem collections, or even on the internet. Some were donated to me by colleagues and even students, and some originated in files of old exams at various universities which I have visited in the course of my career. Since, over the years, I did not keep track of their sources, all I can do is offer a collective acknowledgement to all those to whom it is due. Good problem formulators, like the God of the abbot of Cîteaux, know their own. Deliberately, difficult exercises are not marked with an asterisk or other symbol. Solving exercises is an integral part of learning mathematics and the reader is definitely expected to do so, especially when the book is used for self-study. Try them all and remember the “grook” penned by the Danish genius Piet Hein: *Problems worthy of attack / Prove their worth by hitting back*.

Solving a problem using theoretical mathematics is often very different from solving it computationally, and so strong emphasis is placed on the interplay of theoretical and computational results. Real-life implementation of theoretical results is perpetually plagued by errors: errors in modeling, errors in data acquisition and recording, and errors in the computational process itself due to roundoff and truncation. There are further constraints imposed by limitations in time and memory available for computation. Thus the most elegant theoretical solution to a problem may not lead to the most efficient or useful method of solution in practice. While no reference is made to particular computer software, the concurrent use of a personal computer equipped symbolic-manipulation software such as MAPLE, MATHEMATICA, MATLAB, or MUPAD is definitely advised.

In order to show the “human face” of mathematics, the book also includes a large number of thumbnail photographs of researchers who have contributed to the development of the material presented in this volume.

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