This book is a comprehensive design text for permanent magnets and their application. Permanent magnets are very important industrially, and are widely used in a variety of applications, including industrial drives, consumer products, computers and automobiles.

In the early 1970s a new class of magnet – the rare earths – was discovered, the properties of which showed sustained improvement over the following two decades. New materials such as these have spawned many new markets for magnets, with significant performance gains in the devices for which they are used. By the early 1990s the new magnet technologies had matured. Until the advent of the present book, however, there has been no text that unified all the relevant information on the wide range of modern permanent magnet materials. This book, therefore, has been written as a comprehensive review of the technology, intended for scientists and engineers involved in all stages of the manufacture, design and use of magnets. A brief theory of magnetism explains the behavior of the different classes of permanent magnet, and the various production processes that lead to quite diverse material characteristics. The core of the book is a detailed treatment of the methods that are used to design permanent magnets, including assessments of the changes they experience under practical operating conditions. Modern analytical techniques are described, including the finite element method, with reference to the accurate simulation of permanent magnet materials. With the evolution of new materials, the markets for permanent magnets have changed. In this book, the author emphasizes the most important modern applications, and discusses the viability of the various magnet types that are now available.

This book, the first to cover comprehensively all aspects of modern permanent magnet materials, their design and application, will be of value to anyone involved in the design and use of magnets.

PERMANENT MAGNET MATERIALS AND THEIR APPLICATION

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Preface

The original inspiration to write this book came when, after an electrical engineering training in the late 1960s, I embarked upon the design of a variety of permanent magnet electrical machines. I needed to know more about the behavior and performance of the different magnet materials than the electromechanical design texts provided, and significantly more applications data than the scientific books on magnetism contained. This shortcoming was exacerbated in the early 1970s when an entirely new class of magnet – *the rare earths* – was discovered, offering a vast array of new opportunities for permanent magnet devices, and new challenges to designers such as myself. As these new materials were developed, their properties exhibited dramatic improvements from year to year, reaching maturity in the early 1990s as a full range of samarium–cobalt and neodymium–iron–boron magnets. Until this had happened, I felt that any attempt to produce a comprehensive text including a description of these materials would have been premature. Now, with first-hand experience in most cases, I am able to describe their selection and design for a wide range of important applications.

The material for this book has evolved from courses given to students and practicing engineers while I was at the University of Cambridge and the University of Southern California, and from a variety of assignments to develop and design permanent magnet materials. Though this is intended mainly as a design text, I thought it important to open with an explanation of the theory of permanent magnetism, so the rationale for the various production processes can be understood, leading to the distinct properties of the different classes of magnet. Nevertheless, the core of this book is a detailed treatment of the methods that are used to design permanent magnets, but an important practical consideration is the changes that occur in material properties due to environmental conditions.

The difference between *design* and *analysis* is emphasized, and an appropriate simulation for a permanent magnet is described for each technique, including the popular finite element method.

With the addition of the rare earth class of magnet to the existing ferrite and alnico types, there are new devices, which represent significant new markets for magnets, and there are existing devices whose performance has been substantially improved by changing to a modern material. The selection and optimization of a permanent magnet for the most important applications is described in this book, but the list of products is noticably different from any that would have appeared prior to commercialization of the rare earths. My hope is that the information contained in this book will make manufacturers, designers and users aware of the very broad range of properties available from today's permanent magnets, and arm them with the skills necessary to develop more, successful, new products.

Los Angeles, California *Peter Campbell*