
Preface

Whatever else may be said concerning the two decades following World War II, they have been wonderful years for science. All of the scientific countries of the world have contributed to the great increase in knowledge. Although advances have been made in almost all areas, some have been favored over others. One of the subjects that has received the greatest attention is that of magnetism. Although the appearance of a vast amount of literature is in itself laudable, it has created educational problems. The scientist or engineer who desires or requires an integrated knowledge of magnetism has found it increasingly difficult to satisfy this need. This book was written with such readers primarily in mind.

The material between these covers has formed the basis for several solid state courses offered at the University of Minnesota since 1958. Some of the more elementary parts have been employed for the third quarter of a first course in solid state physics. However, the major use of this text has been as a three-quarter graduate course in magnetism. The students attending the lectures have come from chemistry, physics, electrical engineering, physical metallurgy, and geophysics departments. Since the backgrounds of the audience varied so much, the course was developed by starting as far as possible from first principles. However, it was necessary to begin somewhere, and consequently, first courses in solid state physics and quantum mechanics were usually assumed as prerequisites.

Magnetic phenomena are discussed both from an experimental and theoretical point of view. The plan has been first to present the underlying physical principles and then to follow up with appropriate macroscopic or microscopic theories. Although quantum mechanical theories are given, a phenomenological approach is emphasized. More than half the

book is devoted to a discussion of strongly coupled dipole systems, and in this area the molecular field theory is stressed. The principles and theories have been illustrated by selections from the experimental data, and various tables have been included in an attempt to give some idea of the scope of the literature. Very few references to 1964 papers are included because of publication deadlines.

The utter impossibility of completely surveying all aspects of the subject may be illustrated by considering the *1964 Magnetic Materials Digest*.¹ This publication, which attempts to summarize the 1963 literature pertaining to fundamental studies of ordered magnetic materials, contains more than 1700 references! The particular topics chosen to be discussed at greatest length in this book were determined, as it is usually put, by my own interests. This, of course, really means my own knowledge, experience, talents, and limitations as shaped by contact with colleagues, teaching assignments, and availability of research and travel grants. The coverage of some topics, for example alloys and superconductivity, inadequately reflects the number and extent of current investigations. Other topics, for example, magnetohydrodynamics, group theoretical analysis, and the magnetoelectric effect, have been completely omitted. Nevertheless, the book is rather long and indeed contains more material than can normally be covered in a one-year course.

The question of notation has been a vexing problem. In a book as comprehensive as this one, there are simply not enough symbols to go around. A partial solution has been sought in the use of different kinds of type for the same letter. For example, μ and μ represent the dipole magnetic moment and the permeability, H and \mathcal{H} represent the magnetic field and Hamiltonian, and D , \mathfrak{D} , and \mathfrak{D} represent the demagnetizing factor, the crystal field spin parameter, and the Dzialoshinski vector, respectively. Even so, it was found necessary sometimes to employ the same symbol for more than one quantity; it is only hoped that the context will reduce, if not entirely remove, the danger of ambiguity. Although in general I have tried to adhere to the symbols commonly found in the literature, some deliberate departures have been made. In publications on nuclear magnetic resonance, and to some degree in electron paramagnetic resonance, T with some subscript denotes relaxation time. However, I prefer to reserve T for either temperature or period of time and have therefore taken the liberty of representing relaxation times by τ plus a subscript; this usage at least has the merit of being consistent with that in all other branches of science and engineering. Other, though less important examples, include the use of M_H for the magnetization

¹ A. H. Morrish, R. J. Prosen, and S. M. Rubens, editors, *1964 Magnetic Materials Digest*, M. W. Lads Publishing Co., Philadelphia, Pa. (1964).

along the direction of an applied field, H_1 for the amplitude of an alternating magnetic field, H_e for the effective magnetic field, H_m for the molecular field, J_e for an exchange interaction constant, T_{FN} for the Néel temperature of a ferrimagnet, and N with some subscript for the Weiss molecular field constants. For the Bohr magneton a choice between μ_B and β was possible; I have selected μ_B mainly because β also represents an angle or the relativistic quantity v/c . I have substituted the term "uncompensated poles" for "free poles," since the latter may be taken to imply the existence of monopoles, and they have never been observed in nature. The phrase "intensity of magnetization," common in the British literature, has been eliminated on the grounds that it is both inappropriate and inept. The symbol e for the elementary electric charge represents either type; that is, a negative number is to be substituted for an electron and a positive number for a proton or positron. Except as otherwise noted, the gaussian cgs system of units is employed.

There remains the pleasant task of thanking those who have played some role in the production of this book. I am very grateful to Professor A. J. Dekker, now at Groningen, The Netherlands, who first interested me in doing research in solid state physics and who encouraged me to write this book. I have been fortunate in having Professor W. F. Brown, Jr., as a colleague during part of my tenure at the University of Minnesota. The discussions we have had have left their imprint on a number of these pages. In addition, a critical reading of the first chapter by Dr. Brown has led to its improvement. The response and comments of my graduate students have greatly aided me in the removal of errors, inconsistencies, and obscurities. They have also demonstrated that almost all the problems are soluble. I am indebted to the many publishers and individuals who have given me permission to reproduce figures and tables; these sources are acknowledged at the pertinent places in the text. Finally, I wish to thank my wife for her help with the arduous tasks of proofreading and index preparation.

*University of Manitoba
Winnipeg, Canada
April 1965*

ALLAN H. MORRISH