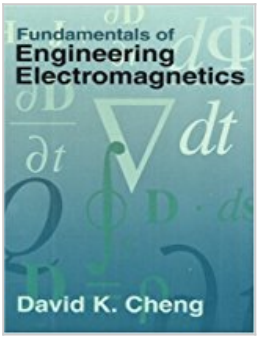

Fundamentals of Engineering Electromagnetics

By David K. Cheng

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This is a derivative publication of Dr Cheng's Field and Wave Electromagnetics (2nd edition). It has been developed in response to the need for a text that supports the mastery of this difficult subject. Therefore, in addition to presenting electromagnetics in a concise and logical manner, the text includes end-of-section review questions, worked examples, boxed remarks that alert students to key ideas and tricky points, margin notes, and point-by-point chapter summaries. Examples and applications invite students to solve problems and build their knowledge of electromagnetics. Application topics include: electric motors, transmission lines, waveguides, antenna arrays and radar systems.

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Editorial Review

From the Inside Flap

This book is designed for use as an undergraduate text on engineering electromagnetics. Electromagnetics is one of the most fundamental subjects in an electrical engineering curriculum. Knowledge of the laws governing electric and magnetic fields is essential to the understanding of the principle of operation of electric and magnetic instruments and machines, and mastery of the basic theory of electromagnetic waves is indispensable to explaining action-at-a-distance electromagnetic phenomena and systems.

Because most electromagnetic variables are functions of three-dimensional space coordinates as well as of time, the subject matter is inherently more involved than electric circuit theory, and an adequate coverage normally requires a sequence of two semester-courses, or three courses in a quarter system. However, some electrical engineering curricula do not schedule that much time for electromagnetics. The purpose of this book is to meet the demand for a textbook that not only presents the fundamentals of electromagnetism in a concise and logical manner, but also includes important engineering application topics such as electric motors, transmission lines, waveguides, antennas, antenna arrays, and radar systems.

I feel that one of the basic difficulties that students have in learning electromagenetics is their failure to grasp the concept of an electromagnetic model. The traditional inductive approach of starting with experimental laws and gradually synthesizing them into Maxwell's equations tends to be fragmented and incohesive; and the introduction of gradient, divergence e, and curl operations appears to be ad hoc and arbitrary. On the other hand, the extreme of starting with the entire set of Maxwell's equations, which are of considerable complexity, as fundamental postulates is likely to cause consternation and resistance in students at the outset. The question of the necessity and sufficiency of these general equations is not addressed, and the concept of the electromagnetic model is left vague.

This book builds the electromagnetic model using an axiomatic approach in steps--first for static electric fields, then for static magnetic fields, and finally for time-varying fields leading to Maxwell's equations. The mathematical basis for each step is Helmholtz's theorem, which states that a vector field is determined to within an additive constant if both its divergence and its curl are specified everywhere. A physical justification of this theorem may be based on the fact that the divergence of a vector field is a measure of the strength of its flow source and the curl of the field is a measure of strength of its vortex source. When the strengths of both the flow source and the vortex source are specified, the vector field is determined.

For the development of the electrostatic model in free space, it is only necessary to define a single vector (namely, the electric field intensity E) by specifying its divergence and its curl as postulates. All other relations in electrostatics for free space, including Coulomb's law and Gauss's law, can be derived from the two rather simple postulates. Relations in material media can be developed through the concept of equivalent charge distributions of polarized dielectrics.

Similarly, for the magnetostatic model in free space it is necessary to define only a single magnetic flux density vector B by specifying its divergence and its curl as postulates; all other formulas can be derived from these two postulates. Relations in material media can be developed through the concept of equivalent current densities. Of course, the validity of the postulates lies in their ability to yield results that conform with experimental evidence.

For time-varying fields, the electric and magnetic field intensities are coupled. The curl E postulate for the

electrostatic model must be modified to conform with Faraday's law. In addition, the curl B postulate for the magnetostatic model must also be modified in order to be consistent with the equation of continuity. We have, then, the four Maxwell's equations that constitute the electromagnetic model. I believe that this gradual development of the electromagnetic model based on Helmholtz's theorem is novel, systematic, pedagogically sound, and more easily accepted by students.

A short Chapter 1 of the book provides some motivations for the study of electromagnetism. It also introduces the source functions, the fundamental field quantities, and the three universal constants for free space in the electromagnetic model. Chapter 2 reviews the basics of vector algebra, vector calculus, and the relations of Cartesian, cylindrical, and spherical coordinate systems. Chapter 3 develops the governing laws and methods of solution of electrostatic problems. Chapter 4 is on steady electric current fields and resistance calculations. Chapter 5 deals with static magnetic fields. Chapter 6, on time-varying electromagnetic fields, starts with Faraday's law of electromagnetic induction, and leads to Maxwell's equations and wave equations. The characteristics of plane electromagnetic waves are treated in Chapter 7. The theory and application s of transmission lines are studied in Chapter 8. Further engineering applications of electromagnetic fields and waves are discussed in Chapter 9 (waveguides and cavity resonators) and Chapter 10 (antennas, antenna arrays, and radar systems). Much of the material has been adapted and reduced from my larger book, Field and Wave Electromagnetics, but in this book I have incorporated a number of innovative pedagogical features.

Each chapter of this book starts with an overview section that provides qualitative guidance to the topics to be discussed in the chapter. Throughout the book worked-out examples follow important formulas and quantitative relations to illustrate methods for solving typical problems. Where appropriate, simple exercises with answers are included to test students' ability to handle related situations. At irregular intervals, a group of review questions are inserted after several related sections. These questions serve to provide an immediate feedback of the topics just discussed and to reinforce students' qualitative understanding of the material. Also, a number of pertinent remarks usually follow the review questions. These remarks contain some points of special importance that the students may have overlooked. When new definitions, concepts, or relations are introduced, short notes are added in the margins to emphasize their significance. At the end of each chapter there is a summary with bulleted items summarizing the main topics covered in the chapter. I hope that these pedagogical aids will prove to be useful in helping students learn electromagentics and its applications.

Many dedicated people, besides the author, are involved in the publication of a book such as this one. I wish to acknowledge the interest and support of Senior Editor Eileen Bernadette Moran and Executive Editor Don Fowley since the inception of this project. I also wish to express my appreciation to Production Supervisor Helen Wythe for her friendly assistance in keeping the production on schedule, as well as to Roberta Lewis, Amy Willcutt, Laura Michaels, and Alena Konecny for their contributions. Jim and Rosa Sullivan of Tech-Graphics were responsible for the illustrations. To them I offer my appreciation for their fine work. Above all, I wish to thank my wife, Enid, for her patience, understanding and encouragement through all phases of my challenging task of completing this book.

D.K.C.

From the Back Cover

Fundamental of Engineering Electromagnetics not only presents the fundamentals of electromagnetism in a concise and logical manner, but also includes a variety of interesting and important applications. While adapted from his popular and more extensive work, *Field and Wave Electromagnetics*, this text incorporates a number of innovative pedagogical features. Each chapter begins with an overview, which serves to offer

qualitative guidance to the subject matter and motivate the student. Review questions and worked examples throughout each chapter reinforce the student's understanding of the material. Remarks boxes following the review questions and margin notes throughout the book serve as additional pedagogical aids.

Back Cover

Fundamentals of Engineering Electromagnetics is a shorter version of Dr. Cheng's best-selling **Field and Wave Electromagnetics, Second Edition. Fundamentals** has been written in summaries. Emphasizes examples and exercises that invite students to build their knowledge of electromagnetics by solving problems.
Besides presenting electromagnetics in a concise and logical manner, the text covers application topics such as electric motors, transmission lines, waveguides, antennas, antenna arrays, and radar systems.

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D.K.C.

Users Review

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Lillie Moreland:

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