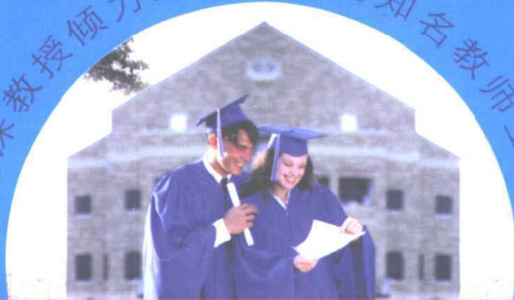
国外资深教授倾力之作　国内知名教师全力推荐



国外高校电子信息类优秀教材

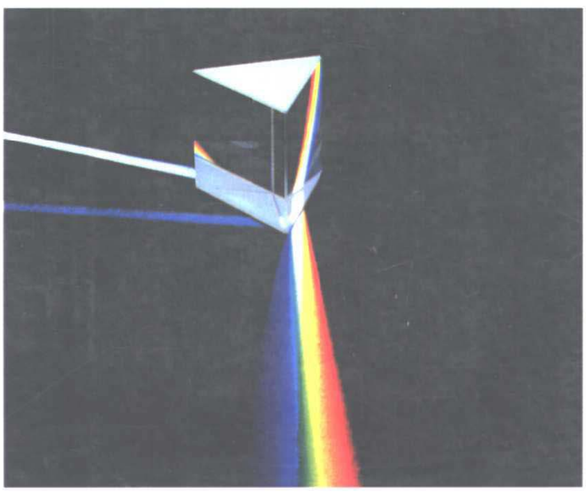
应用电磁学基础

（2001年多媒体版）

Fundamentals of Applied Electromagnetics

(2001 Media Editon)

（英文影印版）



Fawwaz T. Ulaby 著

科学出版社

Pearson Education
培生教育出版集团

内 容 简 介

本书为国外高校电子信息类优秀教材（英文影印版）之一。

本书在电路和电磁学之间架起了一座桥梁，从学生熟悉的概念出发，由浅入深地介绍了应用电磁学方面的基础知识，重点介绍其在通信系统、雷达、光学和计算机系统等方面的应用。

随书所附光盘能帮助学生更形象地理解电磁学。

本书适用于高等院校电气、电子、信息、控制、机电类专业本科生，也可供一般工程技术人员参考。

图字:01-2002-2769

图书在版编目(CIP)数据

应用电磁学基础/(美)乌拉比(Ulaby, F. T.)著. —影印本. —北京:科学出版社,2002

(国外高校电子信息类优秀教材)

ISBN 7-03-010604-0

Ⅰ.应…　Ⅱ.乌…　Ⅲ.电磁学-高等学校-教材-英文　Ⅳ.O441

中国版本图书馆 CIP 数据核字(2002)第 046825 号

科学出版社 出版

北京东黄城根北街16号

邮政编码:100717

http://www.sciencep.com

西源印刷厂 印刷

科学出版社发行　各地新华书店经销

*

2002年6月第 一 版　开本:787×1092 1/16

2002年6月第一次印刷　印张:28 3/4

印数:1—3 000　字数:680 000

定价:46.00元(含光盘)

(如有印装质量问题,我社负责调换〈北燕〉)

When this book was first taught from, each student was asked to write a brief statement describing his or her understanding of what role electromagnetics plays in science, technology, and society. The following statement, submitted by Mr. Schaldenbrand, who has since graduated with a B.S.E. degree, was selected for inclusion here:

> *Electromagnetics has done more than just help science. Since we have such advanced communications, our understanding of other nations and nationalities has increased exponentially. This understanding has led and will lead the governments of the world to work towards global peace. The more knowledge we have about different cultures, the less foreign these cultures will seem. A global kinship will result, and the by-product will be harmony. Understanding is the first step, and communication is the means. Electromagnetics holds the key to this communication, and therefore is an important subject for not only science, but also the sake of humanity.*

Mike Schaldenbrand
EECS 332, Winter 1994
The University of Michigan

Love is life's wonder!

I dedicate this book to Jean.

THE 2001 MEDIA EDITION: INTRODUCING AN INTERACTIVE CD-ROM

Students often complain that the subject matter taught in electromagnetics (EM) courses is mathematically demanding and rather "abstract" in character. Due to the vector nature of EM fields, vector algebra is an essential tool for gaining a quantitative understanding of EM concepts and their applications at a level deeper than the usually qualitative rendition characteristic of introductory physics courses, but it's also true that vector operators, such as the gradient and the divergence, are indeed difficult to visualize in three-dimensional space. The "abstract" criticism made by students derives from the fact that the electric and magnetic fields, E and H, are each comprised of a magnitude (intensity) and a direction, and each of those two features may in general vary with x, y, z, and t, which amounts to a possible maximum of 16 spatial and temporal variations simultaneously! Fortunately, E and H are coupled to one another, and in the majority of cases of practical interest their spatial variations describe continuous, and often symmetrical, patterns, which reduces the dimensional complexity considerably. Nonetheless, when teaching an EM course, the instructor is challenged by the problem of how to effectively convey to the students the workings of a dynamic phenomenon using static tools, namely figures and illustrations.

The CD-ROM introduced with the 2001 edition of this book was designed to address some of the concerns voiced by students by serving as an interactive self-study supplement to the text. It contains video demonstrations, graphical displays, interactive drill exercises, and solutions of some end-of-chapter problems. Examples include video demonstrations showing how the E and H fields inside a coaxial line, as well as the charge distributions on the conductors and the current flow along the conductor surfaces, vary as a function of time and location along the length of the line; video animations of pulses bouncing back and forth between the two ends of a transmission line; propagating waves undergoing reflection by and transmission across boundaries; two-dimensional graphical displays of the E and H fields induced by charges and currents, and a number of exercises involving vector operators. The demos and exercises—162 in total—do not cover every topic in the textbook; they were designed instead to focus on about 25 topics that are somewhat challenging for students to learn. The CD-ROM contains four types of materials:

1. Interactive modules designed to help the student develop better understanding of certain electromagnetic concepts through combinations of video animations and/or drill exercises. The book contains a total of 77 modules each identified by the letter M followed by its numeric designation; M2.1, for example, refers to Module 1 of Chapter 2.

2. Demonstration exercises that utilize spatial displays of field distributions or temporal plots of certain quantities to convey the dynamic nature of electromagnetic fields and the roles of key parameters. Each of the 85 demonstrations is identified by the letter D, as in D6.1

3. Under the section entitled "Solved Problems," the CD-ROM contains complete solutions for 45 problems, selected from among the end-of-chapter problems appearing in the book. Those selected for inclusion in the CD-ROM are identified by the symbol next to the problem statement.

4. Copies of all figures appearing in the book, made available to facilitate the process of reproducing the figures practicably by instructors who may want to generate viewgraphs of the figures electronically.

Message to the Student

The interactive CD-ROM accompanying this book was developed with you, the student, in mind. Take the time to use it in conjunction with the material in the textbook. The multiple-window feature of electronic displays makes it possible to design interactive modules with "help" icons to guide the student through the solution of a problem when needed. Video animations can show you how fields and waves propagate in time and space, how the beam of an antenna array can be made to scan electronically, and examples of how current is induced in a circuit under the influence of a changing magnetic field. The CD-ROM is a useful resource for self-study. Use it!

Message to the Instructor

I found the demos contained in the CD-ROM to be extremely helpful in explaining certain EM concepts, particularly when both time and space are involved. Examine D8.3 as an example and you'll see what I mean. With that demo, it was so much easier to explain to the students the concepts of travelling and standing waves, how boundary conditions are satisfied at the interface between two dissimilar media, and what we mean by standing wave ratio. The video presentations were well received by the students and generated a lot of questions. I hope you will make use of these demos also, especially if you have the means to project them onto a large screen.

I would like to take this opportunity to thank Leland Pierce and Janice Richards for their technical assistance in the CD-ROM development and my Prentice Hall editors, Mr. Tom Robbins and Mr. Eric Frank, for their encouragement and enthusiastic support of the project.

Fawwaz T. Ulaby
Ann Arbor, Michigan

PREFACE

Why Another EM Book?

Several textbooks are currently available for teaching electromagnetics to students majoring in electrical engineering. So, why do we need another one? The answer is simple: (1) the curriculum for a bachelor's degree in electrical engineering is undergoing a radical change, perhaps more radical in both outlook and content than any of the curricular changes we have witnessed over the past several decades, and (2) available textbooks are incompatible with the philosophy of the new curriculum proposed for the 21st century (see, for example, the article by Director et al. in the *Proceedings of the IEEE*, September 1995).

The Changing Curriculum

For a bachelor's degree in electrical engineering, the curriculum has undergone about one major change per decade. In the 1960s, courses concerning solid-state devices were introduced and those on vacuum-tube electronics were slowly phased out. In the 1970s, courses on electric machinery nearly disappeared from the curricula of most universities and were replaced with computer-programming courses. More computer-related and digital processing courses were added in the 1980s, mainly by increasing the volume of required courses and reducing the number of technical and free electives. Also, there has been a sustained effort to incorporate new knowledge and assimilate the rapidly evolving role of technology in the undergraduate curriculum. More material was added to courses, greater effort was expected from students, and the number of elective credit hours rapidly approached zero. By the early 1990s, the average student at a U.S. university needed closer to five years to complete what was originally designed as a four-year program.

This scenario was not limited to electrical engineering; indeed, in almost any engineering discipline, the curriculum had become too demanding in terms of time to complete the B.S. degree and too inflexible to accommodate changes. From these pressures was born a new philosophy embracing the following tenets: (1) the B.S. degree program should be scaled back to four years, (2) the required part of the B.S. degree program should focus on the teaching of fundamentals, but with greater exposure to engineering applications, and (3) the electives portion of the program should be increased substantially to allow the student to explore both engineering and nonengineering areas of interest. While this new philosophy has been adopted, as least in principle, by many engineering schools, the task of revising the curriculum has been a major challenge, particularly at the course level. The new electrical engineering curriculum calls for allocating fewer credit hours in many of the traditionally core areas—electromagnetics (EM) among them. At many universities the required EM content of the program has been reduced from two courses down to one. For some, the intent is to continue to offer a two-course sequence, but with only the first being part of the required core and the second being for students interested in deepening their knowledge in electromagnetics.

Course Contents

Given these objectives and associated boundary conditions, what then should be the contents of a one-semester or a two-course sequence in electromagnetics and what texts might one use for this purpose? To answer these questions, we should briefly review the traditional approaches that have been in use over the past two decades. Most EM books share a common template. They begin with one or more chapters on vector calculus and coordinate systems, followed by two or more chapters on statics (electrostatics and magnetostatics). These topics typically constitute half of the total material, and the second half usually covers dynamics (time-varying fields, wave propagation and reflection, waveguides and resonators, and antennas). Such an arrangement of topics presents two problems. First, starting a course with a heavy dose of mathematics tends to "turn the students off." And second, whereas electrostatics and magnetostatics are interesting subjects in themselves and have many practical applications, their importance pales in comparison with the many applications of time-varying fields to communication systems, radar, optics, computers, and solid-state electronics, among others. Thus, teaching statics only in the required portion of the B.S. degree curriculum would leave an electrical engineering student seriously lacking in ability to deal with most electromagnetic phenomena.

Because of the heavy emphasis on mathematical manipulations using vector calculus and the relatively dry character of electrostatics and magnetostatics, the student who completes such a required course is unlikely to select to take the second course in the sequence, which is where many of the topics relevant to engineering practice are covered. Clearly, teaching from a book based on this traditional sequence of topics is no longer compatible with the format of the new curriculum proposed for the 21st century.

In past years, attempts have been made by educators at various universities to teach the dynamics of electromagnetics without preceding it with a study of statics. These attempts have not been very successful, primarily because in dynamics students must deal with several fundamental parameters simultaneously. These include spatial coordinates denoting location, vectors denoting direction, time, and the interconnection between the electric and magnetic fields. In statics, the electric and magnetic fields are independent of one another and time is not a variable, thereby reducing the number of parameters from four to two. By studying electrostatics and magnetostatics first, the student can much more easily tackle situations involving time-varying fields.

This Book

In view of this background, how then does one design an appropriate one-semester or two-course sequence in electromagnetics? My answer to this question is characterized in this book by the following elements:

1. I wanted to begin by building a bridge between what was already familiar to a third-year electrical engineering student and the electromagnetics material. Prior to enrolling in an EM course, a typical student will have taken two or more courses in circuits. Thus, he or she is familiar with circuit analysis, Ohm's law, Kirchhoff's current and voltage laws, and related topics. Transmission lines constitute a *natural* bridge between electric circuits and electromagnetics. Without having to deal with vectors or fields, the student uses already familiar concepts to learn about wave motion, the reflection and transmission of power, phasors, impedance matching, and many of the properties of wave propagation in a guided structure. All of these newly learned concepts will prove invaluable later (in Chapters 7 through 9) and will facilitate the learning of how plane waves propagate in free space and in material media. Transmission lines are covered in Chapter 2, which is preceded in Chapter 1 with reviews of complex numbers and phasor analysis.

2. The next part of the book, contained in Chapters 3 through 5, covers vector analysis, electrostatics, and magnetostatics. Compared with most EM textbooks written for undergraduate instruction, the present book differs in terms of its presentation of these three topics in the following two ways: Of the total number of pages contained in the book, about 30% are allocated to these topics, compared with 50% or more in most EM textbooks. The electrostatics chapter begins with Maxwell's equations for the time-varying case, which are then specialized to electrostatics and magnetostatics, thereby providing the student with an overall framework for what is to come and showing him or her why electrostatics and magnetostatics are special cases of the more general time-varying case.

3. Unlike most EM textbooks, this book does not have a chapter on waveguides and resonators. Space limitations and the fact that waveguides are no longer used as widely as they had been prior to 1980 dictated this change.

4. Chapter 6 deals with time-varying fields and sets

Suggested Syllabi

	Two-semester Syllabus 6 credits (42 contact hours per semester)		**One-semester Syllabus** 4 credits (56 contact hours)	
Chapter	Sections	Hours	Sections	Hours
1 Introduction	All	4	All	4
2 Transmission Lines	All	12	2-1 to 2-8 and 2-11	8
3 Vector Analysis	All	8	All	8
4 Electrostatics	All	8	4-1 to 4-10	6
5 Magnetostatics	All	7	5-1 to 5-5 and 5-7 to 5-8	5
Exams		3		2
	Total for first semester	42		
6 Maxwell's Equations	All	6	6-1 to 6-3, and 6-6	3
7 Plane-wave Propagation	All	7	7-1 to 7-4, and 7-6	6
8 Wave Reflection and Transmission	All	9	8-1 to 8-3, and 8-6	7
9 Radiation and Antennas	All	10	9-1 to 9-6	6
10 Satellite Communication Systems and Radar Sensors	All	5	None	—
Exams		3	1	
	Total for second semester	40	Total	56
Extra Hours	2	0		

the stage for the material in Chapters 7 through 9. Chapter 7 covers plane-wave propagation in dielectric and conducting media, and Chapter 8 covers reflection and transmission at discontinuous boundaries and introduces the student to fiber optics and the imaging properties of mirrors and lenses.

In Chapter 9, the student is introduced to the principles of radiation by currents flowing in wires, such as dipoles, as well as to radiation by apertures, such as a horn antenna or an opening in an opaque screen illuminated by a light source.

5. To give the student a taste of the wide-ranging applications of electromagnetics in today's technological society, Chapter 10 concludes the book with overview presentations of two system examples: satellite communication systems and radar sensors.

6. The material in this book was written for a two-semester sequence of six credits, but it is possible to trim it down to generate a syllabus for a one-semester four-credit course. The above table provides syllabi for each of these two options.

In writing this book, I avoided lengthy derivations of theorems, particularly those involving extensive use of vector calculus. My goal has been to help the student to develop competence in applying vector calculus to solve electromagnetic problems of practical interest. I view vector calculus and mathematics in general as useful tools and not as ends in themselves. Throughout the material, emphasis is placed on using the mathematics to explain and clarify the physics, followed with practical examples intended to demonstrate the engineering relevance of physical concepts. I believe the combination of the approach used in presenting the material, the arrangement of topics covered in the book, and the relative emphasis in favor of dynamics constitutes an effective algorithm for equipping our future graduates with a relevant foundation in applied electromagnetics.

Acknowledgments

In writing this book I have been fortunate to have had valuable help from many talented individuals. First and foremost, I would like to acknowledge my most sincere gratitude to Roger DeRoo, Richard Carnes and Jim Ryan. I am indebted to Roger DeRoo, not only for the numerous discussions we have had on how to best present electromagnetic concepts and applications, without getting lost in the mathematics, but also for his painstaking review of several drafts of the manuscript. Richard Carnes is unquestionably the best technical typist I have ever worked with; his mastery of LaTeX, coupled with his attention to detail, made it possible to arrange the material in a clear and smooth format. The artwork was done by Jim Ryan, who skillfully transformed my rough sketches into drawings that are both professional looking and esthetically pleasing.

I would like to thank my colleagues at the Radiation Laboratory of the University of Michigan for their advice and support and, in particular, I gratefully acknowledge Linda Katehi, Chen-To Tai and Kamal Sarabandi for their generous counsel and constant encouragement. Thanks also are due to my students, who have suffered through two semesters of having a text in the form of notes and who have provided many suggestions for improving and clarifying the presentation. Moreover, I am grateful to the following graduate students for reading through parts or all of the manuscript and for helping me with the solutions manual: Bryan Hauck, Yanni Kouskoulas, and Paul Siqueira.

I am grateful to the reviewers for their valuable comments and suggestions. They include Constantine Balanis of Arizona State University, Harold Mott of the University of Alabama, David Pozar of the University of Massachusetts, S. N. Prasad of Bradley University, Robert Bond of New Mexico Institute of Technology, Mark Robinson of the University of Colorado at Colorado Springs, and Raj Mittra of the University of Illinois. I appreciate the dedicated efforts of the staff at Prentice Hall and I am grateful for their help in shepherding this project through the publication process in a very timely manner. I also would like to thank Mr. Ralph Pescatore for copyediting the manuscript.

Fawwaz T. Ulaby
Ann Arbor, Michigan

CONTENTS