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—— 信息技术学科与电气工程学科系列

6

Electromagnetics with Applications

Fifth Edition

电磁学及其应用

第 5 版

Kraus
Fleisch



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ELECTROMAGNETICS

with Applications

Fifth Edition

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出版说明

郑大钟

清华大学信息技术科学与技术学院

当前,在我国的高等学校中,教学内容和课程体系的改革已经成为教学改革中的一个非常突出的问题,而为数不少的课程教材中普遍存在“课程体系老化,内容落伍时代,本研层次不清”的现象又是其中的急需改变的一个重要方面。同时,随着科教兴国方针的贯彻落实,要求我们进一步转变观念扩大视野,使教学过程适应以信息技术为先导的技术革命和我国社会主义市场经济的需要,加快教学过程的国际化进程。在这方面,系统地研究和借鉴国外知名大学的相关教材,将会对推进我们的课程改革和推进我国大学教学的国际化进程,乃至对我们一些重点大学建设国际一流大学的努力,都将具有重要的借鉴推动作用。正是基于这种背景,我们决定在国内推出信息技术学科和电气工程学科国外知名大学原版系列教材。

本系列教材的组编将遵循如下的几点基本原则。(1)书目的范围限于信息技术学科和电气工程学科所属专业的技术基础课和主要的专业课。(2)教材的范围选自于具有较大影响且为国外知名大学所采用的教材。(3)教材属于在近5年内所出版的新书或新版书。(4)教材适合于作为我国大学相应课程的教材或主要教学参考书。(5)每本列选的教材都须经过国内相应领域的资深专家审看和推荐。(6)教材的形式直接以英文原版形式印刷出版。

本系列教材将按分期分批的方式组织出版。为了便于使用本系列教材的相关教师和学生从学科和教学的角度对其在体系和内容上的特点和特色有所了解,在每本教材中都附有我们所约请的相关领域资深教授撰写的影印版序言。此外,出于多样化的考虑,对于某些基本类型的课程,我们还同时列选了多于一本的不同体系、不同风格和不同层次的教材,以供不同要求和不同学时同类课程的选用。

本系列教材的读者对象为信息技术学科和电气工程学科所属各专业的本

科生,同时兼顾其他工程学科专业的本科生或研究生。本系列教材,既可采用作为相应课程的教材或教学参考书,也可提供作为工作于各个技术领域的工程师和技术人员的自学读物。

组编这套国外知名大学原版系列教材是一个尝试。不管是书目确定的合理性,教材选择的恰当性,还是评论看法的确切性,都有待于通过使用和实践来检验。感谢使用本系列教材的广大教师和学生的支持。期望广大读者提出意见和建议。

Electromagnetics with Applications

(第5版)

影印版序

本书,《Electromagnetics with Applications》(Fifth Edition)(电磁学及其应用)(第5版),是美国 McGraw-Hill 出版社最近出版的一本电磁理论及其应用方面的大学本科教材。该书第一版出版于 1953 年,其后于 1973,1984,1992 年多次修订再版。在全世界高等学校的电机与电子工程系被广泛采用作为教材或教学参考书,具有很大影响。

在本书的开始首先给出电磁学中的量纲、单位制及矢量分析的基础知识,然后作为主体全面叙述电磁学即电磁场与电磁波的经典理论。包括恒定电磁场,集总参数电路元件中的电磁场,传输线的分布参数电路理论和场理论,平面波的传播、衰减、偏振、反射、折射和衍射,天线和电磁辐射,荷电粒子、载流子及载流导体在电磁场中的运动,介电材料和磁性材料,波导和谐振器等。在此基础上进一步介绍了电磁学的最新进展和应用,如直线电机,雷达,卫星通信,全球卫星定位,无线移动通信,光纤光学,生物电磁学,高速数字电路中的电磁效应等的基本概念。最后给出求解电磁场问题的数值方法。

本书具有以下显著的特点:

1. 理论叙述深入浅出,不罗列艰深的公式及数学推导,只给出最基本的和最必要的数学公式。重点在于清晰的物理叙述。使一般认为很抽象的电磁场与电磁波以一种生动、具体、实在的图像呈现在读者面前。与此同时,全书的理论叙述又是严格的和深入的,介绍了许多与近代物理有关的知识。

2. 理论与实际紧密联系。在理论叙述的同时,针对各种参数和物理量给出了大量数据图表,给读者建立一个清晰的“量”的概念。所有数据图表都是根据严格的科学实验结果制成的。

3. 书中大量的插图,绘制精美,匠心独具,为本书增色不少。其中一部分是描述电磁场基本原理的插图,有助于读者形象地理解相应的物理原理;另一部分是与电磁有关的基本物理现象的图示,深入地揭示了许多自然现象;还有一部分是以插图的形式描述电磁理论的应用原理。

4. 本书在电磁学应用方面的内容独具特色。给出了范围广泛的应用实例,并对其电磁学原理进行了确切的解释。

5. 本书的另一个特点是给出大量的例题和习题。这些例题和习题并不是简单的套用理论或照猫画虎,而是着眼于知识的扩大和深化。有的习题涉及很深入的理论问题或很具体的应用问题,具有极强的启发性。

6. 随着多次的修订补充,本书始终能反映科技的最新发展。在本版(第5版)中,对地面基站和卫星基站的移动通信系统,同步卫星通信系统,卫星全球定位系统(GPS),射电望远镜,生物电磁学及电磁兼容等领域的最新进展都有出色的描述。在最后数值解法一章中介绍了较新的方法,如FD-TD法等。

本书的主要作者,约翰·克劳斯博士(Dr. John D. Kraus),目前是美国俄亥俄州立大学(Ohio State University)的荣誉教授,美国工程院院士。早在二战之前,他从密西根大学(Michigan University)获得博士学位后,即在该校从事世界上最大的回旋加速器的研究工作。在二战期间他加入海军并在哈佛大学无线电研究所(Radio Research Laboratory, Harvard University)进行无线电研究。战后,从1946年起,担任俄亥俄州立大学电机工程教授,同时兼任物理学和天文学教授。1954年,他设计和领导建造了俄亥俄州立大学110米射电天文望远镜,占地比三个足球场还大,是世界上口径价格比最高的抛物面天线。在很长时间内,它是地面上最强有力的深空观测装置。该望远镜一直工作到1998年,做出了不少有价值的观测和发现。克劳斯博士曾多次获得科技奖,如俄亥俄州沙利文金奖(Sullivant Gold Medal),美国电工和电子学会(IEEE)爱迪生金奖和赫兹金奖。他是一位长期从事首创性科学工作的学者,或者可以说是半个世纪以来电磁科学发展的亲历者,既具有深厚的理论造诣,又有丰富的实际经验。正因为如此,才有可能写出这样一部出色的教材。

当然,与以上优点同时存在的不足是,有些公式的来龙去脉交待得不够详细,出现得比较突然。另外,除第9章给出一些有关生物电磁学的原始参考文献外,其他章节未列出参考书和参考文献。读者在阅读中遇到困难时,只能自己查阅有关书籍、文献。

总之,本书不着重追求艰深的理论演绎,不陷入繁琐的、普遍性的数学推导,而是帮助读者学到完整的、具体的和生动的电磁学知识,是一部与国内目前流行的教科书的风格很不相同的教材,很值得一读。许多学生认为电磁场理论抽象、艰深、难学,读这部书一定会获得很大帮助。本人作为从事电磁理论教学工作的教师很愿意将此书推荐给学习“电磁学”,“电磁场理论”或“电动力学”的学生作为一部有价值的参考书。清华大学出版社准备出版这部书的影印版,这对我国师生引用国外优秀教材,借鉴国外教学经验是一件很有意义的事。为本书在中国出版,作了以上的序,见解或有不当,请读者指正。

张克潜

清华大学电子工程系教授
2001年5月18日于清华园

*To Michael Faraday, who performed the
pioneering experiments,*

*To James Clerk Maxwell, who used them to
formulate the all-encompassing theory
of electromagnetics, and*

*To Heinrich Hertz, whose experiments validated
the theory and gave us wireless.*

ABOUT THE AUTHORS

John Kraus received his B.S., M.S., and Ph.D. degrees from the University of Michigan. For several years he did research with the University's 100-ton cyclotron, then the world's most powerful particle accelerator. During World War II he was with the U.S. Navy and Harvard University's Radio Research Laboratory. Joining the Ohio State University Electrical Engineering faculty in 1946, he was also a member of the faculties of Physics and Astronomy.

Dr. Kraus has published hundreds of scientific and technical articles. He also is the author of several widely translated books: *Antennas* (1950), *Electromagnetics* (1953), *Radio Astronomy* (1966), and *Big Ear* (1976), all now in newer editions. He was elected a member of the National Academy of Engineering in 1972. He has received numerous medals and awards, including the Sullivant gold medal of Ohio State and the Edison and Heinrich Hertz gold medals of the Institute of Electrical and Electronic Engineers.

Daniel Fleisch received his B.S. degree from Georgetown University and his M.S. and Ph.D. degrees from Rice University. For several years he did upper atmosphere research at the Arecibo, Puerto Rico, and Jicamarca, Peru, ionospheric observatories. Later, he did design work for a company producing microelectronic equipment.

In 1993 Dr. Fleisch joined Aeroflex-Lintek of Powell, Ohio, as Chief Scientist. Concurrently, he is on the faculty of Wittenberg University.

PREFACE

With the explosive growth of wireless technology and with less time available in curricula, this book is structured to get to practical applications early. The first five chapters form the basic core with the last five providing supplementary material that can be used as desired. The book is designed for a one-semester or two-quarter course with a variety of assignment options. A few assignment schedules are given on page xix.

The book has 11 chapters:

Chapter 1. Introduction. Explains the language of electromagnetics and gives an introduction to vector analysis.

Chapter 2. Electric and Magnetic Fields. Provides a concise but thorough introduction to the fundamental concepts culminating in Maxwell's equations.

Chapter 3. Transmission Lines. Explains them from both circuit and field viewpoints with early reference to the ubiquitous microstrip line. Discusses matching and the propagation of both continuous signals and short pulses.

Chapter 4. Wave Propagation, Attenuation, Polarization, Reflection, Refraction and Diffraction. Waves in space and their interaction with media are discussed with analogies to wave behavior on transmission lines.

Chapter 5. Antennas, Radiation, and Wireless Systems. Basic antenna concepts are followed by array theory and the design of over two dozen types of antennas with many applications to wireless systems. The many topics include pulsed and doppler radar, global position systems, and passive remote sensing.

Chapter 6. Electrodynamics. Gives a concise treatment of particle dynamics and the operation of cathode-ray-tubes, motors and generators both mechanical and Hall.

Chapter 7. Dielectric and Magnetic Materials. Provides further information about dielectric and magnetic materials with sections on dielectric polarization, magnetization, and hysteresis.

Chapter 8. Waveguides, Resonators, and Fiber Optics. Covers wave propagation in rectangular and circular guides, along dielectric sheets and fibers and waves trapped inside a resonator.

Chapter 9. Bioelectromagnetics. A short but important chapter on the electromagnetics of living systems, radiation hazards, and related environmental issues.

Chapter 10. Electromagnetic Effects in High-Speed Digital Systems. Another short but important chapter with insights into the role of electromagnetics in the design and proper operation of high-speed digital systems. Includes a discussion of electromagnetic interference (EMI), electromagnetic compatibility (EMC), government regulations and testing procedures.

Chapter 11. Numerical Methods. An important chapter on repetitive Laplace or the finite difference method, the integral equation and the moment method, finite element, and other methods. These are accompanied by computer programs in Appendix C.

Appendixes. Include tables of units, material constants, mathematical formulas, computer programs, and other useful relations.

The format of this edition is modular. Explanatory material is typically followed by a worked example and problems with answers. At the end of each chapter are many additional problems and also a few instructive projects that may be assigned with or without extra class credit.

It would not have been possible to prepare this edition without the dedicated assistance of Dr. Erich Pacht, who has been involved in all aspects of the editorial process. Dr. Jerry Ehman has provided great assistance in proofing both text and problems. We have also benefited from the comments and suggestions of many others who have read all or parts of the manuscript. These include: Richard Mallozzi, University of California, Berkeley; Professor Benedikt Munk, Ohio State University; and the McGraw-Hill reviewers Professors Jim Akers, Mississippi State University; Brian Austin, Liverpool University; Keith Carver, University of Massachusetts; Elbadawy Elsbarawy, Arizona State University; Haralambos Kritikos, University of Pennsylvania; Raymond Luebbers, Pennsylvania State University; Irene Peden, University of Washington; and Andrew Peterson, Georgia Institute of Technology. The McGraw-Hill editors and supervisors Lynn Cox, Nina Kreiden, Betsy Jones, Emily Gray, and Kimberly Schau were most helpful.

Finally, John Kraus thanks his wife, Alice, for her patience, encouragement, and dedication through all the years of work it has taken, and Daniel Fleisch thanks Jill for her constant support.

Supplementary material, new examples, and projects are available on the book's Web site: www.elmag5.com.

A word about *wireless*. After Heinrich Hertz first demonstrated radiation from antennas, it was called *wireless* (German: *drahtlos*, French: *sans fils*). And wireless it was until broadcasting began about 1920 and the word *radio* was introduced. Now *wireless* is back to describe the many systems that operate without wires as distinguished from *radio* which to most persons now implies AM or FM.

Suggested Assignments
8 pages per class day (avg.)

Chapter	One Semester			Two Quarters		
	Days/Chapter			Days/Chapter		
1	3			3		
2	9			9		
3	5			5	Second quarter	
	Exam 1			Exam 1	Optional	
4	9		Basics	9	↓	↓
5	12			2	10	10
	Exam 1			Exam 1		
6		Optional		30	3	3
7		↓		First quarter	5	6
		↓		Exam 1	1	1
8		2		4	5	3
9	2			2	2	1
10	2			2	2	1
11			4	2		5
	Exam 1	1	1	Exam 1	1	1
	<u>45</u>	<u>45</u>	<u>45 days</u>	<u>30</u>	<u>30</u>	<u>30 days</u>

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