

教育部高等教育司推荐
国外优秀信息科学与技术系列教学用书

电磁波理论(中)

影印版

Electromagnetic Wave Theory (2)

■ JIN AU KONG

高等教育出版社
Higher Education Press

EMW Publishing

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前 言

20 世纪末，以计算机和通信技术为代表的信息科学和技术对世界经济、科技、军事、教育和文化等产生了深刻影响。信息科学技术的迅速普及和应用，带动了世界范围信息产业的蓬勃发展，为许多国家带来了丰厚的回报。

进入 21 世纪，尤其随着我国加入 WTO，信息产业的国际竞争将更加激烈。我国信息产业虽然在 20 世纪末取得了迅猛发展，但与发达国家相比，甚至与印度、爱尔兰等国家相比，还有很大差距。国家信息化的发展速度和信息产业的国际竞争能力，最终都将取决于信息科学技术人才的质量和数量。引进国外信息科学和技术优秀教材，在有条件的学校推动开展英语授课或双语教学，是教育部为加快培养大批高质量的信息技术人才采取的一项重要举措。

为此，教育部要求由高等教育出版社首先开展信息科学和技术教材的引进试点工作。同时提出了两点要求，一是要高水平，二是要低价格。在高等教育出版社和信息科学技术引进教材专家组的努力下，经过比较短的时间，第一批引进的 20 多种教材已经陆续出版。这套教材出版后受到了广泛的好评，其中有不少是世界信息科学技术领域著名专家、教授的经典之作和反映信息科学技术最新进展的优秀作品，代表了目前世界信息科学技术教育的一流水平，而且价格也是最优惠的，与国内同类自编教材相当。

这项教材引进工作是在教育部高等教育司和高教社的共同组织下，由国内信息科学技术领域的专家、教授广泛参与，在对大量国外教材进行多次遴选的基础上，参考了国内和国外著名大学相关专业的课程设置进行系统引进的。其中，John Wiley 公司出版的贝尔实验室信息科学研究中心副总裁 Silberschatz 教授的经典著作《操作系统概念》，是我们经过反复谈判，

做了很多努力才得以引进的。William Stallings 先生曾编写了在美国深受欢迎的信息科学技术系列教材，其中有多种教材获得过美国教材和学术著作协会颁发的计算机科学与工程教材奖，这批引进教材中就有他的两本著作。留美中国学者 Jiawei Han 先生的《数据挖掘》是该领域中具有里程碑意义的著作。由达特茅斯学院的 Thomas Cormen 和麻省理工学院、哥伦比亚大学的几位学者共同编著的经典著作《算法导论》，在经历了 11 年的锤炼之后于 2001 年出版了第二版。目前任教于美国 Massachusetts 大学的 James Kurose 教授，曾在美国三所高校先后 10 次获得杰出教师或杰出教学奖，由他主编的《计算机网络》出版后，以其体系新颖、内容先进而倍受欢迎。在努力降低引进教材售价方面，高等教育出版社做了大量和细致的工作。这套引进的教材体现了权威性、系统性、先进性和经济性等特点。

教育部也希望国内和国外的出版商积极参与此项工作，共同促进中国信息技术教育和信息产业的发展。我们在与外商的谈判工作中，不仅要坚定不移地引进国外最优秀的教材，而且还要千方百计地将版权转让费降下来，要让引进教材的价格与国内自编教材相当，让广大教师和学生负担得起。中国的教育市场巨大，外国出版公司和国内出版社要通过扩大发行数量取得效益。

在引进教材的同时，我们还应做好消化吸收，注意学习国外先进的教学思想和教学方法，提高自编教材的水平，使我们的教学和教材在内容体系上，在理论与实践的结合上，在培养学生的动手能力上能有较大的突破和创新。

目前，教育部正在全国 35 所高校推动示范性软件学院的建设和实施，这也是加快培养信息科学技术人才的重要举措之一。示范性软件学院要立足于培养具有国际竞争力的实用性软件人才，与国外知名高校或著名企业合作办学，以国内外著名 IT 企业为实践教学基地，聘请国内外知名教授和软件专家授课，还要率先使用引进教材开展教学。

我们希望通过这些举措，能在较短的时间，为我国培养一大批高质量的信息技术人才，提高我国软件人才的国际竞争力，促进我国信息产业的

快速发展，加快推动国家信息化进程，进而带动整个国民经济的跨越式发展。

教育部高等教育司

二〇〇二年三月

PREFACE

This book presents a unified macroscopic theory of electromagnetic waves in accordance with the principle of special relativity from the point of view of the form invariance of the Maxwell equations and the constitutive relations. Great emphasis is placed on the fundamental importance of the \bar{k} vector in electromagnetic wave theory. We introduce a fundamental unit $K_o = 2\pi \text{ meter}^{-1}$ for the spatial frequency, which is cycle per meter in spatial variation. This is similar to the fundamental unit for temporal frequency Hz, which is cycle per second in time variation. The unit K_o is directly proportional to the unit Hz; one K_o in spatial frequency corresponds to 300 MHz in temporal frequency.

This is a textbook on electromagnetic wave theory, and topics essential to the understanding of electromagnetic waves are selected and presented. Chapter 1 presents fundamental laws and equations for electromagnetic theory. Chapter 2 is devoted to the treatment of transmission line theory. Time-harmonic fields are introduced in Chapter 3 to study propagation, reflection, transmission, guidance, and resonance of electromagnetic waves. Starting with Čerenkov radiation, we study radiation and antenna theory in Chapter 4. Chapter 5 then elaborates on the various theorems and limiting cases of Maxwell's theory important to the study of electromagnetic wave behavior. Scattering by spheres, cylinders, rough surfaces, and volume inhomogeneities are treated in Chapter 6. In Chapter 7, we present Maxwell's theory from the point of view of Lorentz covariance in accordance with the principle of special relativity.

The problem section at the end of each section provides useful exercise and applications. The various topics in the book can be taught independently, and the material is organized in the order of increasing complexity in mathematical techniques and conceptual abstraction and sophistication. This book has been used in several undergraduate and graduate courses that I have been teaching at the Massachusetts Institute of Technology. The undergraduate course covers Chapters 1 and 2 without topic 1.2A and Sections 1.3B, 1.8 and 1.9. The introductory graduate course covers Chapters 1, 3, 4 and parts of Chapter 5. The rest of the book is used for advanced graduate courses.

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PROPAGATION AND GUIDANCE

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- B. Constitutive Relations and Dispersive Media
- C. Time-Average Poynting Power Vector
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3.6 Resonance

- A. Rectangular Cavity Resonator
- B. Circular Cavity Resonator
- C. Spherical Cavity Resonator

Topic 3.6A Cavity Perturbation

Answers

3.1 Time-Harmonic Fields

For electromagnetic waves of a particular frequency in the steady state, the fields are time-harmonic and are known as monochromatic waves or continuous waves (CW). The CW cases are important for three reasons: (i) the CW assumption can be used to eliminate the time dependence in the Maxwell equations and thus considerably simplify the mathematics; (ii) once the CW case is solved and a sound understanding is developed for the frequency-domain phenomena, Fourier theory can be applied to study the time-domain phenomena; (iii) CW representation covers the whole spectrum of electromagnetic waves. Clearly, a thorough understanding of CW or the time-harmonic case is essential in the study of all electromagnetic wave phenomena.

For a time-harmonic field with angular frequency ω , we let

$$\overline{E}(\bar{r}, t) = \text{Re}\{\overline{E}(\bar{r}) e^{-i\omega t}\} \quad (3.1.1)$$

where Re denotes the real part of a complex quantity and $e^{-i\omega t}$ denotes the convention of time dependence used in the rest of this book. To convert to the previous convention of $e^{j\omega t}$, simply replace i by $-j$. The current convention of $e^{-i\omega t}$ facilitates integration on the upper half of a complex plane and connects to conventions used in literature on physical sciences. The complex electric field vector $\overline{E}(\bar{r})$ is a function of position only and independent of time. In this book we do not use different symbols to distinguish real quantities such as $\overline{E}(\bar{r}, t)$ in the time domain and complex quantities such as $\overline{E}(\bar{r})$ in the frequency domain. Their meanings should be clear from the context. In case of possible ambiguity, we shall explicitly indicate the complex field quantities to be functions of \bar{r} only and the real time-domain fields to be functions of both \bar{r} and t .

A. Maxwell Equations for Time-Harmonic Fields

Similar definitions apply to other field quantities with \overline{E} replaced by \overline{H} , \overline{B} , \overline{D} , \overline{J} , and ρ in (3.1.1). Substituting $\overline{E}(\bar{r}, t)$ and $\overline{B}(\bar{r}, t)$ in Faraday's law (1.1.2) we obtain

$$\text{Re}\{[\nabla \times \overline{E}(\bar{r}) - i\omega \overline{B}(\bar{r})]e^{-i\omega t}\} = 0 \quad (3.1.2)$$

This equation is true for all time t .

Note: When the real part of the complex quantity in the square brackets multiplied by all values of $e^{-i\omega t}$ is equal to zero, the complex quantity