Advanced Series in Electrical and Computer Engineering – Vol. 4

Introduction to Engineering Electromagnetic Fields

Korada Umashankar

World Scientific

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World Scientific
Singapore • New Jersey • London • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.,
P O Box 128, Farrer Road, Singapore 9128
USA office: 687 Hartwell Street, Teaneck, NJ 07666
UK office: 73 Lynton Mead, Totteridge, London N20 8DH

Library of Congress Cataloging-in-Publication data is available.

INTRODUCTION TO ENGINEERING ELECTROMAGNETIC FIELDS

ISBN 9971-50-921-0
9971-50-922-9 pbk

Printed in Singapore by JBW Printers & Binders Pte. Ltd.

To my wife Prabha

and my sons Sachidananda and Sundaresh

Preface

The *Introduction to Engineering Electromagnetic Fields* is principally intended as the required text book for the senior level undergraduate electrical engineering students and for the preparatory level graduate engineering students. Even the researchers in the area of analytical and computational electromagnetics find this text book useful as a quick reference guide for the basic analytical expressions in engineering electromagnetic fields and applications. The author has taught electromagnetics and engineering applications for past eighteen years. This test book is the collection of series of class lecture notes and feedback from students' interaction on the foundation to engineering electromagnetic topics which have been presented to the undergraduate and preparatory graduate level electrical engineering students. It is generally assumed that the reader knows fundamental differential calculus, integral calculus and in particular solution to simple differential equations. Vector calculus is generally recommended. The undergraduate students who have already taken introductory vector calculus will find this text book easy to understand.

The text book contains seventeen chapters. Each chapter has been prepared with self contained material keeping in mind that the cross referencing of the subject material should be as far as minimum. The first chapter presents a brief discussion on the vector calculus. In fact, attempt has been made to introduce vector calculus as and when necessary throughout text book. This allows the student to pickup the concept of electric and magnetic fields in an elegant manner. Eventually, in order to understand the complete subject material, it is necessary to know all about vectors and their mathematical theorems which are also indirectly discussed in this book in terms of the electromagnetic fields.

The book is written to introduce partially static and then partially dynamic electromagnetic fields. The chapters from two to six discuss the fundamentals of electrostatic fields. The Coulomb's law, the Gauss's law are introduced here. Similarly, the chapters from seven to eleven discuss the fundamentals of magnetostatic fields. The Biot-Savart's law, the Gauss's law and the Ampere's law are introduced here. There exists one to one correspondence between the study of electrostatic fields and magnetostatic fields. The Poisson's and Laplace's equations are also discussed with simple examples about the static fields. The chapters twelve to

fifteen basically discuss the dynamic electric and magnetic fields. Based on the Faraday's law and the Ampere's law, the classical Maxwell's equations are discussed in time domain in the chapter twelve and correspondingly in frequency domain in the chapter fourteen. The solution to the time domain Maxwell's equations and wave equations is considered in the chapter thirteen. The corresponding solution to the frequency domain Maxwell's equations and Helmholtz equations is considered in the chapter fifteen. Emphasis is primarily given to the study of electromagnetic fields in the rectangular coordinate system. In order to excite the reader's interest and to show basic engineering concepts, the last two chapters expose simple applications of the Maxwell's equations to the problems of electromagnetic field radiation in a free space medium and also propagation of the electromagnetic fields in a guided wave structure.

The text book is self contained with discussion based on simple examples which are sufficient to pick up general concepts of the electromagnetic field theory. If desired the students may refer to the list of references given in the bibliography which are useful for further reading. The area of electromagnetic fields and engineering applications is high demanding in the various related engineering fields dealing with state-of-the-art modern technological developments which require knowledge of the field theory. The recent advancements in the area of numerical methods and computer technology is pushing gradually the electromagnetic field studies beyond its present limits. It is highly recommended that the undergraduate students start studying the field theory with problem solving based on computers and graphical display of field calculations.

The author wishes to express his sincere appreciation to Dr. Wai-Kai Chen, Professor and Head of the Department of Electrical Engineering and Computer Science, University of Illinois at Chicago for the encouragement received to write this text book and to Prof. K.K.Phua of the World Scientific for publishing this text book among their series in electrical and computer engineering. The author also wishes to acknowledge good efforts of Mr. Sainath Nimmagadda, Ph.D. graduate student in the Department of Electrical Engineering and Computer Science for proof reading and verifying all the mathematical developments in the manuscript.

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February 24, 1989

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