# ELEMENTS OF ENGINEERING ELECTROMAGNETICS

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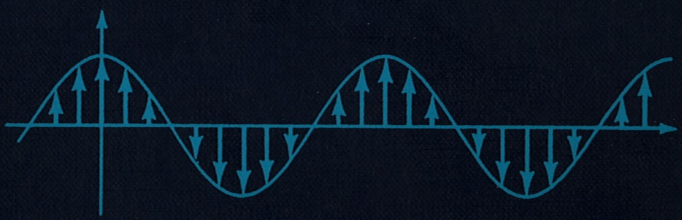

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There is a Subhashitam (Worthy Saying) in Sanskrit, which says:

Annadaanam param daanam
Vidyadaanam atahparam
Annena kshanikam triptih yaavajjiivamcha vidyayaa.

The gift of food is a great gift
Greater still is the gift of knowledge
While food provides a momentary contentment, knowledge provides a lasting fulfillment.

This "webook (web + book)" constitutes the gift, by the author and his department, of the knowledge of the subject of electromagnetics, based on Maxwell's equations, which "today underpin all modern information and communication technologies."

To the memory
of
MY FATHER

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# PREFACE

Traditionally, the first undergraduate course in engineering electromagnetics has been based upon developing static fields in a historical manner, and culminating in Maxwell's equations, with perhaps a brief discussion of uniform plane waves. This is then followed by one or more courses dealing with transmission lines and wave propagation. Due to the pressure of increasing areas of interest and fewer required courses, there has been in recent years a growing trend in electrical engineering curricula toward limiting the requirement in electromagnetics to a one-semester course or its equivalent. Consequently, and in view of the student's earlier exposure in engineering physics to static fields and Maxwell's equations, it has become increasingly expedient to deviate from the historical approach and to base the first course in electromagnetics upon dynamic fields and their engineering applications.

There are many texts, including one by the author, which fulfill the requirements of the traditional approach. There are also several books devoted to wave propagation and related topics; these, however, rely upon a first course of the traditional type or a variation of it to provide the required background. Thus a need has arisen for a one-semester text in which the basic material is built up on time-varying fields and their engineering applications so as to enhance its utility for the one-semester student of engineering electromagnetics, while enabling the student who will continue to take futher (elective) courses in electromagnetics to learn many of the same field concepts and mathematical tools and techniques provided by the traditional treatment. This book represents an attempt to satisfy this need.

The thread of development of the material is evident from a reading of the table of contents. Some of the salient features of the first nine chapters consist of introducing:

1. the bulk of the material through the use of the Cartesian coordinate system to keep the geometry simple and yet sufficient to learn the physical concepts and mathematical tools, while employing the other coordinate systems where necessary;
2. Maxwell's equations for time-varying fields first in integral form and then in differential form very early in the book;
3. uniform plane wave propagation by obtaining the field solution to the infinite plane current sheet of uniform sinusoidally time-varying density;
4. material media by considering their interaction with uniform plane wave fields;
5. transmission lines by first considering uniform plane waves guided by two parallel, plane perfect conductors and then extending to a line of arbitrary cross section through graphical field mapping;
6. waveguides by considering the superposition of two obliquely propagating uniform plane waves and then placing perfect conductors in appropriate planes so as to satisfy the boundary conditions;
7. antennas by obtaining the complete field solution to the Hertzian dipole through a successive extension of the quasistatic field solution so as to satisfy simultaneously the two Maxwell's curl equations; and
8. Maxwell's equations for static fields as specializations of Maxwell's equations for time-varying fields and then proceeding with the discussion of the more important topics of static and quasistatic fields.

The final chapter is devoted to seven independent special topics, each based upon one or more of the previous six chapters. It is intended that the instructor will choose one (or more) of these topics for discussion following the corresponding previous chapter(s). Material on cylindrical and spherical coordinate systems is presented as appendices so that it can be studied either immediately following the discussion of the corresponding material on the Cartesian coordinate system or only when necessary.

From considerations of varying degrees of background preparation at different schools, a greater amount of material than can be covered in an average class of three semester-hour credits is included in the book. Since it has been found that nearly eight chapters can be completed during the semester, the first six chapters plus an equivalent of about two chapters from the remaining four is suggested to be typical of coverage. When the background preparation permits an accelerated discussion of the first three chapters, it is possible to cover a greater amount of material. Worked-out examples

are distributed throughout the text to illustrate and, in some cases, extend the various concepts. Summary of the material and a number of questions are included for each chapter to facilitate review of the chapters. Problems are arranged in the same order as the text material, and answers are provided for the odd-numbered problems.

This text is based primarily on lecture notes for classes taught by the author at the University of Illinois at Urbana–Champaign. The author wishes to express his appreciation to Patricia Sammann for the excellent typing work. Finally, although great care has been exercised, some errors are inevitable. The author earnestly requests readers to inform him of any errors that they may find and to contribute suggestions for improvement.

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