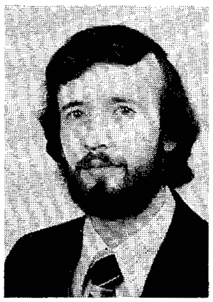
Reviews and Abstracts



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BOOK REVIEW

Advanced Engineering Electromagnetics, by Constantine A. Balanis, John Wiley and Sons, New York, 1989, xx + 981 pages, ISBN: 0-471-62194-3, price: $66.50.

This volume is a welcome addition to the collection of texts available for adoption in graduate electromagnetic theory courses. Given its length, collection of topics, and readability, it is clearly appropriate for a two-semester course in advanced electromagnetic theory. It also will find considerable use as a reference text.

Many classic textbooks which are presently used as graduate texts are quite old and, hence (while theoretically sound), lacking in coverage of some important, modern topics. Ideally, a new text should include fundamental theory (such as material relationships, potential theory, and uniqueness theorems), and canonical examples (such as modes in a rectangular waveguide, and scattering from a circular cylinder), which would also be covered in the classic texts. In addition, some topics with less contemporary relevance (such as the low-loss circular waveguide) should be de-emphasized, and contemporary examples (such as microstrip and optical fibers) added. Using this criteria as a measure, this text succeeds. To see this, it is useful to list the chapter headings. They are as follows:

1. Time-Varying and Time-Harmonic Electromagnetic Fields
2. Electrical Properties of Matter
3. Wave Equation and Its Solutions
4. Wave Propagation and Polarization
5. Reflection and Transmission
6. Auxiliary Vector Potentials, Construction of Solutions and Radiation and Scattering Equations
7. Electromagnetic Theorems and Principles
8. Rectangular Cross-Section Waveguides and Cavities
9. Circular Cross-Section Waveguides and Cavities
10. Spherical Transmission Lines and Cavities
11. Scattering
12. Integral Equations and the Moment Method
13. Geometrical Theory of Diffraction
14. Greens Functions

It is clear that Chapters 1-7 and 14 contain fundamental theory which can be found in many classic texts. For example, content similar to Chapters 1, 2, and 7 can be found in Harrington's book [1]. It is no surprise that there will be quite a bit of overlap, because electromagnetics is not a rapidly changing field. The contribution of any new text in the area of fundamental theory is mostly the readability of the presentation, the coherence of the topics chosen, the discussions on limitations of theory, and the physical interpretation of the mathematics. In addition, there may be a small amount of new material in these sections. I find this book to be readable and coherent, and there is some appropriate contemporary material (e.g., material relationships for superconducting material) in these sections. The questions of limitations and physical interpretation will be discussed in more detail later.

Chapters 8-11 consist, in part, of canonical examples which should be covered in any text (old or new) and, in part, of contemporary applications, which will change with the age of the text. Again, with no surprise, there is much overlap between these chapters and older texts, such as Harrington [1]. Clearly, the rectangular waveguide, the biconical transmission line, and scattering from a conducting circular cylinder are classical canonical examples, and not "new" topics. The dielectric slab and fiber are also canonical, but more relevant today than forty years ago, because of applications in integrated and fiber optics. Thus, it is appropriate that these sections have been expanded. The microstrip is an example of a problem which cannot be solved completely in closed form, but is of sufficient interest today to warrant inclusion. Another example of a more contemporary subject is the section on dielectric resonators, the first I have seen in a general electromagnetic theory text.

Chapters 12 and 13 are introductions to relatively "modern" numerical and asymptotic techniques, used now to solve many electromagnetics problems. It is here that the largest differences between older electromagnetic theory texts and this text will be found. It is also true that much of this material can be found in more modern antenna theory texts [2,3].

I have several other general comments on the book. First, there are useful appendices on identities, vector analysis, special functions, and the method of steepest descents. Second, it appears that the end-of-chapter problems are of sufficient number and level of difficulty to be useful. However, I have not yet used the book in a course, and thus cannot comment in any more detail about the problems. I should point out that a solutions manual for all end-of-chapter problems is available. Third, there are listings of computer programs that can be used by students to try out some of the numerical methods. It would be useful to know whether these are available in disk form. Finally, the author has useful references (and information about how they can be obtained) to other programs which are available, such as the Numerical Electromagnetics Code (NEC).

At this point I would like to make some more specific comments about the text. First, let me emphasize the positive.

I have always liked the chapter in Harrington's book [1] on electromagnetic theorems. I am pleased to find similar material in this text, in Chapters 7 and 14. The subject of Green's functions occupies a full chapter. Several of the nice features in the chapter are a pedagogically helpful section on one-dimensional Green's functions in circuit theory and mechanics, and discussions of the Sturm-Louisville problem and dyadics. As would be expected, there is considerable overlap between the chapter on electromagnetic theorems and Harrington's chapter on theorems. However, there is some added material which I find helpful. One item I especially appreciate is the author's expanded discussion of approximations, based on the induction and physical equivalent formulations. It is very important to recognize the limitations of approximations. This idea is emphasized by the author and is, in fact, one thread which runs throughout the text. The author, for example, discusses the two-dimensional strip scattering problem in both the chapters on scattering and on integral equations, and shows how different approximations, such as PO, PTD, and GTD, compare.

Chapter 2 is an expanded survey of materials properties relevant to electromagnetic theory, which covers dielectrics, magnetic materials, semiconductors, and superconductors, and is far more extensive than that found in Harrington's book [1]. Along with the extensive set of references at the end of the chapter, this section will be a very useful reference on material properties.

The chapter on scattering is quite complete, and is useful reading. One example of a topic usually not found in texts is the scattering of obliquely-incident plane waves by a circular cylinder. This is a good foundation from which a discussion of scattering due to three-dimensional sources can be introduced.

The chapter on integral equations is a good overview of the subject. The topic is introduced with a discussion of the charged wire problem. This is appropriate pedagogically, because the problem is one-dimensional, and the electrostatic potential field is simple and scalar. Thus, the solution method is not obscured by vector notation and more complex kernels. Following this introduction, the more complex integral equations for wire antenna problems and for two-dimensional scattering are tackled. One good feature of the chapter is the discussion of the source modeling problem for antennas (although it doesn't quite get to the point of how to compare numerical results to either results based on the delta-function model, or experimental results, such as found in Elliot's book [5]).

Finally, the Geometric Theory of Diffraction chapter is a well-written introduction to the subject. One feature I like is the discussion of the exact solution to the half-plane scattering problem. By using this as a foundation, the derivation of the edge-diffraction coefficients is not magic, as it is in some texts. Rather, these diffraction coefficients are derived naturally from an asymptotic expansion of the exact half-plane-problem solution. Further, by using the half-plane solution as a basis. the failure of simple GTD at shadow and reflection boundaries, and the rationale for improved diffraction theories, can be easily understood. Another feature of this chapter which I like is the inclusion of curved-edge diffraction. I have not seen this topic in other commonly available texts.

I also have some constructive suggestions for the text. These reflect my bias for emphasizing the limitations of theory, and the development of physical intuition and an understanding about why apparently disparate topics are actually related. It is with some hesitation that I discuss these, because of the already long length of the book. Nevertheless, it is perhaps useful to consider another perspective on the presentation of some of the topics covered in the book.

The relationship between the time-varying case and the time-harmonic case should be explored in more depth, in order to justify a text on "time-harmonic electromagnetic fields." While it is formally possible to transform Maxwell's equations into the frequency domain, via the Fourier transform as is done here, it should be emphasized that linearity is required when materials are present. It should also be mentioned that transform techniques can be used to develop time-domain solutions from the time-harmonic solutions. Finally, there should be some discussion of the movement by many researchers to solve problems directly in the time domain. Some discussion of the advantages and disadvantages of each approach might be useful.

There is always concern in electromagnetics about limitations on solutions, and why these limitations occur. There are several places in the text where discussions of these issues could be strengthened. For example, in the discussion of Huygen's principle, it would be useful (as is done in Stratton's book [4]) to discuss problems which occur when source fields are discontinuous, and thus require additional "Kottler" sources. In the section on uniqueness theorems, it would be useful to discuss edge conditions. If there are re-entrant corners in a problem, uniqueness, as presented in this book, fails, and must be supplemented with edge conditions [6,7].

It is useful in an advanced electromagnetics text to point out that there are alternative methods for solving a specific problem. Given that this is so, it is very helpful to explain why one method might be preferable to another. With this in mind, it could be emphasized more that the vector potentials presented in the text are not unique. It is possible, for example, to use the vector potential, **A**, to completely describe a time-harmonic field. The vector potential, **F**, is introduced , not because it is necessary, but because it is a useful alternative (or complement) to **A**. For example, it might be stated that only one component of **F** is needed to describe the field from an elementary magnetic dipole, while its description in terms of the vector potential, **A**, is more complicated. Thus, a description in terms of **F** is "better". This idea of non-uniqueness can be carried over into the equivalence theorem of Chapter 7, where it is stated that an infinite number of equivalencies are possible, and to the Green's function chapter, since Green's functions represent an alternative way of deriving results obtained from the equivalence principle [1]. It is instructive to discuss reasons why one choice might be "better" than another. This background could lead nicely into a discussion of the choice between the E-field integral equation and the H-field integral equation.

One important concept, that should be discussed with students, is how different pictures of electromagnetic phenomena (e.g., modes and rays) are related. This can be illustrated with a simple parallel-plate waveguide driven by a line source. It is often assumed without comment that the fields inside the waveguide should be described as an infinite set of modes. As an alternative, the solution to this problem can be written in terms of an inverse spatial Fourier transform. The modal solution appears naturally if the inverse transform is evaluated by residue integration. But by using a geometric series expansion in the integrand of the formal solution, an alternative description of the fields, as an infinite set of rays of the same kind as described in the GTD chapter, can be found. This way of approaching the problem has three advantages. First, it again illustrates the idea that there is more than one way to present the solution to a problem, and begs a discussion of why the mode description or the ray description is more useful in a particular case. Second, it gives a simple alternative picture of the wave propagation process. Third, it establishes a continuity between the modal theory, usually used to describe microwave circuits, and the ray theory, usually used to describe high-frequency diffraction. I cannot now find this problem done in this way in any text, but you can find the idea in papers such as [8]. With this as background, I am not particularly satisfied with the author's discussion on "rays" in waveguides. I might add that his discussion is common to many other texts in which this topic is discussed. The method presented is the "pair of plane waves" approach, in which the plane waves are called "rays". These "rays" are not rays in the sense of geometrical-optics rays, as discussed in Chapter 13, and hence are potentially confusing to students. For example, they do not decay by spreading, and require pairs of "rays" to match boundary conditions. I would prefer to see a discussion of ray theory in waveguides (using rays with the same properties as those of Chapter 13) as an alternative to mode theory, but equivalent. This would then be a natural lead in to the topic of geometric optics in Chapter 13.

The quasi-TEM mode is introduced in the section on microstrips and striplines, without any comment about its validity or relationship to other types of modes. It would be useful to have at least a reference, to a paper in which this kind of mode is justified, such as [9].

It is traditional to solve two-dimensional scattering problems in textbooks, without relating them to the real world of three-dimensional problems. Why do we use them? Is it only for illustrative purposes, or is it because they can be related to three-dimensional problems? Some comment would be appropriate. Another topic related to this issue is that of why plane waves are used when they cannot exist individually. Some comment about the spatial Fourier transform as a superposition of plane waves, or about the asymptotic behavior of fields from a source of finite dimension, would help clarify a topic that is often confusing to students.

It would be useful to discuss the relationship between the moment method (sometimes called the boundary element method) and the finite-element method, since both are now popular methods for solving problems. A reference such as [10] would be helpful.

In conclusion, I am impressed with the breadth and readability of this text, and intend to try it in our graduate electromagnetic field theory sequence. I plan, however, to supplement the text with material such as I have discussed above.

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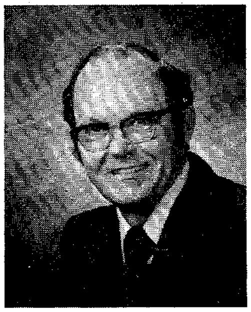

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Scientific Visualization, Visual Electromagnetics, and Visualization Software

Some of you are probably aware of growing activities in the general subject of "scientific visualization," terminology apparently first used in a report recently prepared under auspices of the National Science Foundation ["Visualization in Scientific Computing," *ACM SIGGRAPH*, **21**, November, 1987]. While I and some colleagues have been talking about the use of graphics in EM since the early 1970s, only within the last two years or so have I begun to use the term "Visual Electromagnetics" as a way to emphasize the point. Actually, I adapted that name from Professor Ralph Abraham of UC Santa Cruz, who published three (at least) books in a series he called the Visual Mathematics Library, in which mathematical phenomena of various kinds are displayed graphically without a single equation. This idea is catching on in other areas of science, engineering and mathematics, and even in fields not normally associated with visualization, such as economics [the February 1988 PCs for AP column covered some of these applications]. There the term "Visicon" is being used as a means of describing the increasing variety of graphical presentations being employed for economic data, which in some ways is even more abstract than some of the phenomena with which we deal.

For some time now, I have had the urge to put together a book of EM graphics examples, for which the working title is (what else?) "*Visual electromagnetics*." I mention this because although there are