Preface

These topic notes comprise part of the learning material for *48xxx Fields and Waves*. They are not a complete set of notes. Extra material and examples may also be presented in the face-to-face activities.

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Contact

If you discover any errors or feel that some sections need clarifying, please do not hesitate in contacting me:

Peter McLean
School of Electrical and Data Engineering
Faculty of Engineering and Information Technology
University of Technology Sydney

Office: CB11.11.405 - Building 11 (Broadway), Level 11, Room 11.405
Voice : +61-2-9514-2339
Email : peter.mclean@uts.edu.au
Web : http://www.uts.edu.au/staff/peter.mclean

Introduction

Electric circuit theory and electromagnetic theory are the two fundamental theories upon which all branches of electrical engineering are built. Many branches of electrical engineering, such as power, electric machines, high speed digital circuits, electronics and communications are based on electromagnetic theory. Electromagnetic theory is also valuable to students specializing in other branches of the physical sciences because of the applied mathematics and physics involved.

At the undergraduate level, it is important to impose a particularly disciplined approach to electromagnetic theory that emphasises the conceptual meanings, rather than the mathematical rigour, in the study of fields.

Electromagnetic theory has traditionally appeared to practically-oriented prospective engineers as an academic luxury. Nevertheless, field theory studies have stood the test of time as a portion of virtually all electrical engineering degree courses, because it forms the basis of nearly all the macroscopic equations and concepts employed in electrical engineering. This subject addresses the following areas, in a manner that may help students appreciate that the 'luxury' is worthwhile:

a) An elaboration on the foundation that supports much of circuit theory, machine theory and high-frequency behaviour of electrical systems. The weaknesses and strengths of this foundation tend to produce surprises to accepted notions held by thinking students.

b) The use of this foundation to derive many of the common equations already used by students, pointing out their range of applications as defined by their derivation.

c) The consequent development of new notions for energy flow and current patterns that may assist in a more mature appreciation of high-frequency behaviour, interference and capacitive effects, machine and transmission line modelling.

d) Providing a 'window' to look into some special areas of electrical engineering where field concepts must be used explicitly. Optical and metal waveguides, radiating antennae and receivers, and effective resistances of transmission lines are chosen as the most common examples of these areas.

e) Providing better facility in many mathematical techniques necessary for the aims above, with the hope that this facility permeates to other subjects (particularly in Circuits, Signals and Control strands) using similar techniques. For effective mathematical teaching to engineers, the stress should continually be placed on the physical concepts behind the symbols and operators.

f) The application of some of the electrical system models to other areas of engineering, particularly mechanical, and to familiar everyday systems, to illustrate the wider basis of the mathematical tools.

In human terms, the subject aims to create engineers of a more 'professional' character than would otherwise be the case. Their conceptual knowledge of electromagnetic theory will provide a broader horizon for problem-solving thinking patterns, perhaps making specific techniques a little more enjoyable and meaningful. They may have more confidence (and a little more competence) in assessing an unfamiliar problem, or a problem that apparently contradicts normal circuit behaviour. They may recognise where broader-based field notions must be applied, even if in many cases their experience is not sufficient to develop solutions.

In essence, electromagnetic field theory can be one sma1l tool applied to developing a flexible, analytic and critical mind in a technologically-changing world that needs all the flexible minds it can muster.

Supporting References

There are a vast variety of teaching methods employed in electromagnetic field theory, reflected in the character of texts available. A subset of the volumes that are roughly similar in nature to this subject are listed below:

1. Ramo, S., Whinnery, J.R. and Duzer, J.V.: *Fields and Wave in Communications Electronics*, 2nd *Ed*., John Wiley & Sons, 1984.

   An intermediate-level text which has a strong focus on communications (waveguides, microwave networks, antennas and optics).

2. Magid, L.: *Electromagnetic Fields, Energy and Waves*, Robert Krieger, 1982.

   This reference is the best overall choice for its exhaustive attempts to provide physical meaning by way of discussion and example.

3. Solymar, L.: *Lectures on Electromagnetic Theory*, Oxford 1976.

   The concise descriptions of selected parts of electromagnetism make this volume good introductory 'light reading' to provide a feel for the subject.

4. Rao, N.: *Elements of Engineering Electromagnetics*, Prentice Hal1, l977.

   The notation used by Rao (and by Magid) appears simpler to students than some other alternatives, and the book covers the later parts of the subject with some distinction.

5. Johnk, C.: *Engineering Electromagnetic Fields and Waves*, Wiley, 1975.

   This book is reasonably comprehensive, and particular topics are easy to locate. The treatment is fairly lucid, but suffers from a notation that is not universally clear to new students.

6. Skitek, G. and Marshall, S.: *Electromagnetic Concepts and Applications*, Prentice-Hall, 1982.

   A clear treatment with worked examples, this book should serve well as a support for study with the exception of some gaps in its coverage.

7. Cheng, D.K.: *Field and Wave Electromagnetics*, Addison-Wiley, 1983.

   Presents the material with lucidity, unity and smooth logical flow of ideas. Many worked out examples are included to emphasize fundamental concepts.

8. Griffith, D.: *Introduction to Electrodynamics*, 4th *Ed*., Pearson, 2013.

   A ‘standard’ physics textbook that presents the concepts in a less formal tone, but it lacks engineering context and applications.

9. Pipes, L. and Harvill, L.: *Applied Mathematics for Engineers and Scientists*, 3rd *Ed*., McGraw-Hill, 1971.

   A book that covers all the fundamental mathematical techniques used by engineers, although the terminology is inconsistent and a little dated.

Synopsis

Topics 2 and 4 lay the basis of the macroscopic field concept. The electrostatic field is considered due to an isotropic emission of 'fluid' from every source point. The motion of such sources causes relativistic distortions of spatial dimensions, and in turn distorts the density of field lines. This distortion of the electric field is known as the magnetic field.

Topics 3 and 5 develop these concepts using vector calculus, to provide a summary of the basic equations encompassing electrostatics and magnetostatics.

Topics 6 and 7 develop methods of solving static problems, particularly involving Laplace's equation. Many non-electrical systems also satisfy Laplace's equation, and these are mentioned in Topic 7. A variety of mechanical, hydraulic and thermal systems are modelled by Poisson's equation, Laplace's equation and the diffusion equation.

Topic 8 extends the methods of solution of differential equations, and discusses the particularly important geometry of the twin-cable, two-line-charges or long-dipole problem.

The notion of energy residing in a field, discussed in Topic 9 extends the audacity of fluid concepts (of Topic 2) to their logical limit, and the remaining topics develop the notions to time-varying cases.