Electromagnetic Fields in Electrical Engineering

understanding basic concepts

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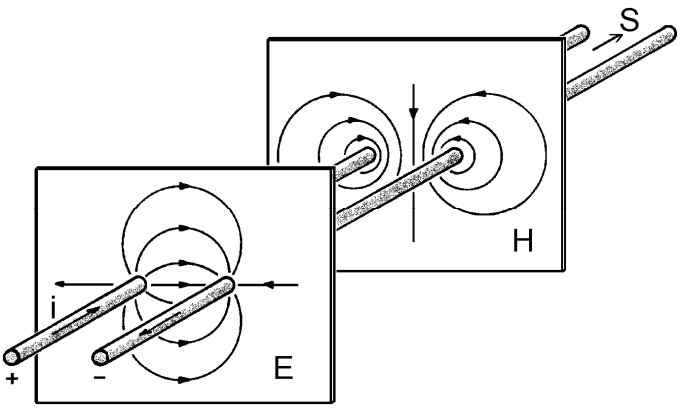

Illustration on the front cover

Electric and magnetic fields, near a pair of leads, shown in two separate planes. Note the direction of the current flow and the polarity of the voltage difference between the two leads.

In reality both *E* and *H* field lines are present in every plane perpendicular to the leads. The pair of leads carries, by means of those E- and H-fields power or signals in the direction of the Poynting vector *S*.

Preface

Electromagnetic Fields in Electrical Engineering, understanding basic concepts

Electrical Engineering has grown enormously during the last century in its number of technical applications and disciplines. As it is still continuing to expand, we wonder how practicing engineers can keep up their expertise and what we should teach students.

In this situation "background" subjects suffer because many rivaling subjects compete for our attention. One of the background subjects is that of electromagnetic fields. Are electromagnetic fields essential elements of Electrical Engineering or are they just annoying side effects? What should we do with our courses on electromagnetic fields?

Actually electromagnetic fields are fundamental to Electrical Engineering. Currents and voltages - and transport of signals or power - cannot exist without magnetic and electric fields. Those fields are even more fundamental than currents and voltages; the fields in waves exist far away from currents in conductors.
Fields are also of crucial importance in Electromagnetic Compatibility, in power engineering and in the design of advanced electronic units.

This book is meant for two groups of readers:
- Practicing electrical engineers who are often confused by radiation and interference problems. Many of them have a rudimentary knowledge of field theory and use only circuit theory, where the fields are hidden.
- Students could use the book in an introductory course on electromagnetic fields, preferably early during the study, before specialization. Some students may follow later additional EM-courses, for others it might be the only course on the subject. Also these students should have a basic understanding of the importance of fields and the limitations of circuit theory.

Most books on electromagnetic fields follow the historical evolution, starting with electrostatics and permanent magnets, later introducing time-variation, induction effects and finally electromagnetic waves. The advantage of that approach is that it follows the interesting historical development over more than two hundred years. Readers may however feel that this lengthy detour is irrelevant for the technology of today.

- In this book we present an overall picture emphasizing the importance of electric and magnetic fields to all disciplines of electrical engineering.
- Maxwell's laws in integral form are introduced early on and are used to demonstrate the similarities between the various disciplines of electrical engineering.
- We focus on basic concepts, on the story behind the equations rather than on detailed mathematics. Too much mathematics in field theory has - unfortunately - convinced many people that circuit theory is more practical and relevant.
- The readers should be familiar with circuit theory, an important and valuable tool in
- electrical engineering. In Chapter 5 we derive the basic equations of circuit theory from field theory. In this chapter we also show the limitations of circuit theory to make it clear when field theory should be used.
- To show the significance of electromagnetic fields all examples are taken from electrical engineering, rather than from physics experiments.

- Many illustrations are necessary to show the essentially three-dimensional nature of the combination of actual circuits and fields. Most illustrations are placed close to the corresponding text in the margin.
- In the last chapter we discuss electromagnetic compatibility (EMC) and methods to eliminate undesirable electromagnetic coupling.

This book is based upon course material in Dutch, used by electrical engineering students at Eindhoven University since 1992. The material has also been useful for many EMC-courses taught outside the university and has proven its merits during much experimental work in laboratories and for industrial partners.

The author acknowledges many friends and colleagues in research laboratories and in universities for numerous helpful discussions on the large variety of field problems we encountered, both in plasma physics and in electrical engineering. In particular he is grateful to the members of the High-voltage and EMC group, now a part of the Electrical Power Systems group led by prof.dr. Jan Blom and later by prof. Wil Kling. Thanks to their continuous and friendly support, research and teaching was a rewarding adventure.
Some of this support is clearly visible in the book. Figures 1.2 and 8.2 were computer-generated by dr. Lex van Deursen, my EMC-colleague. The Figs. 7.1, 7.2, 7.3 and 7.4 were produced by dr. Bert van Heesch and dr. Peter Wouters.

Finally, I am very grateful to my wife, Janny, for encouragement and patience over the years.

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About the Author

Piet van der Laan studied physics at Delft University. From 1959 to 1978 he worked on fusion research, in particular on plasma confinement by magnetic fields, at the FOM-Institute for Plasma Physics in the Netherlands and in the US, where he spent one year at the University of Wisconsin in Madison, one year at MIT and three years at the Los Alamos Scientific Laboratory.
In 1978 he became professor in the Department of Electrical Engineering of Eindhoven University of Technology. His specialty is power engineering, with emphasis on high-voltage discharges, measuring techniques and Electromagnetic Compatibility. In 2000 he officially retired.
In designing experimental machines and in doing difficult measurements, on rapidly compressed plasmas and later on high-power and high-voltage systems the author encountered challenging electric and magnetic field problems.
He is life member of the IEEE and the American Physical Society