Introduction
Electromagnetic Fields and Waves

Why Study EM Fields?

Typically, EM Fields courses are perceived as among the toughest for UG engineering students. The typical reasons for this issue are: 1. Lack of adequate background preparation and 2. Inadequate textbooks and teaching of the material. The topic requires a holistic presentation of the math and physics to ensure student comprehension and appreciation of its importance to their education.

The fact of the matter is that EM fields are pivotal to all aspects of Electrical Engineering. Maxwell's equations provide the foundation for the topics of circuit theory, electronics, communications, power generation and transmission, microwaves and antennas, just to name a few application areas. Borrowing from the computer community, EM fields is like the machine language and the way we deal with these EE topics is like writing the code in a higher-level language.

In addition to developing the insight and appreciation to the roots of the different EE curriculum topics, we site two additional benefits of studying EM fields as an undergraduate. In particular, we site the added skills in both the areas of design and problem solving.

Competent Design Skills?

As an Engineer, you are likely to get involved in the design, analysis, or testing of an electrical or electronic device (or circuit). These devices and circuits are typically made of "conductors", "dielectrics", and possibly "magnetic" media. These different materials are shaped and assembled (or integrated) together in specific manners as to perform certain functionality. When powered up, the electrical charge distribution within the device structure is altered as to produce the desired device function.

Studying electromagnetic fields is about gaining the skill and acquiring the tools that enables the engineer to relate to the physics of electrical charge distributions and currents and their interaction with different materials. In other words, this study is all about developing the appreciation to the properties and limitations of the elements and components we use in electrical and electronic devices.

Some would say that we learned how to design circuits by putting together passive and active components "wired" in certain fashions to produce the desired function. The point is that the models we "claim" for the components we use in circuit design are approximate (simplified) ones that ignore "secondary" features of these components. These models are typically developed through an electromagnetic fields study of the components' physical structures with certain degrees of approximations.

In other words, the "basic" models of passive components, such as resistors, capacitors, inductors, and even interconnecting wires (transmission lines), all are developed based on EM field studies of material structures and their interaction with charge distributions and currents. Similarly, the models of active components (devices), such as diodes, transistors, and various integrated circuits components, require an EM field analysis of how their physical structure and material properties react to different electromagnetic fields excitations.

Not only the models of these components are developed through an EM study of their physical structures, but also, the tools we use in circuit design are developed based on an electromagnetic study as well. Even primary tools like Ohm's law, Kirchhoff's current and voltage laws have their roots in electromagnetic field studies.

To demonstrate, we take an example of a simple resistor component. Typically, designers would use the simplified model of a "pure" resistance in the circuit schematic as well as in the circuit analysis or design equations. The fact of the matter is that the "simple resistor" contains other features that may be ignored in some cases but would be critical to the circuit performance in others. Those other features may include lead inductance, packaging capacitance, material nonlinearities and more. In fact, the model for other features as such requires a field analysis as well, and the resulting component is again an approximation to the actual physical performance of the structure.

Another example is the interconnecting "wires" in a circuit. Typically, those are ignored as having no effect on the circuit performance other than connecting the circuit components to each other. This is a simplification that could lead to serious errors in some applications. Connecting wires contribute to resistive, inductive, and capacitive circuit elements that could alter the circuit performance at high frequencies and high currents.

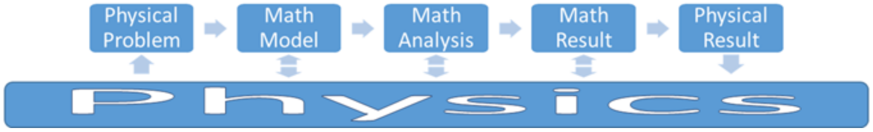
From the above discussion, we can conclude that EM field studies are key to the development of component models we can use in circuit/device design and analysis. We can also conclude that several degrees of modeling "fidelity/accuracy" are possible, and in some cases more approximations suffice than in the others. Consequently, we can extrapolate to say that there will be cases where circuit models will not provide adequate representation of the physical devices, in which case, we must resort to the fundamental tool of EM field analysis.

In essence, a good designer needs to be in full appreciation of the different material properties and how they react to the presence of different charge distributions and currents. Not only that, but a good designer needs to get into other interdisciplinary areas such as mechanical, thermal, and chemical properties, in addition to including environmental, economical, and human factors in the device design.

This book focuses on the basics of EM field studies. It does not provide all the tools required for the learner to become a "good designer" in this regard. However, it provides the foundations of EM field needed to build on with more advanced course work. It certainly attempts to provide the student with the insight of what is needed to be learned to be a "good designer".

__Problem Solving Skills:__

Studying EM fields has the potential of arming the learner with "problem solving" skills. This a fringe benefit that comes naturally with the topic, far beyond what comes through from other courses in his/her curricula. This is manifested in the ability to take a physical problem through the steps of deriving a physically based model for which a mathematical model is then developed. Next, we do the math analysis and obtain results for which we find relevant physical explanations and applications.



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