Description of *Classical Electromagnetism, 2nd Edition:*

My main focus has been to provide a text for the first year graduate course in Electromagnetism that is readable and useful for the students, and easy and useful for professors to teach from. I have tried to keep the text the right length for two 14 week semesters. I do not expect the same time to be spent on each chapter. The earlier ones could be covered faster, but I think they will give a good basis for the more complicated material to come.

The book would also be a useful supplement for undergraduate students who want to go into more depth than is given in their 'junior level' course, or for graduate students to get a better understanding of the subject. The first chapter, by itself, gives a hands-on presentation of vector calculus that would give a good background for future study and research in any field of physics.

I have not included a lot of extra pages on special advanced topics that could not be covered anyway in a first year course. Professors may want to add a special topic of their own choosing using their own notes, but I didn't feel I could guess the right topic for all tastes. I have tried to make this a text to prepare grad students for all future work in physics, without confusing them in their first year. I also do a number of things differently than most current texts on this level:

1. I start most chapters on a basic level, and work up to more advanced material progressively. This is also done in the body of the text. The first several chapters include much material that the student probably has seen before (although I try to be both readable and rigorous in my approach). Some teachers may want to skim some of this early material. This can be done if you have enough confidence in your students. I put a lot of this material in early, because I feel that much of it is often taught badly in earlier courses.

2. I include the mathematics integrally with the physics. Most of the students will have seen this mathematics before, but my comments above also apply here. My feeling is that the math and EM are so entwined that teaching them together enhances understanding of each. Some of the math treatments are in separate sections, so teachers could skim or skip

them, but I do not recommend taking them too lightly. One consequence of my math integration is that there are no flyleaf formulas and few references to advanced math texts. Whatever is needed for EM is here in front of the students as they study the EM, and is developed as it is used.

3. I try as much as possible to use a vector treatment for vector calculus, and to avoid the use of specific coordinate systems (except for Chapter 4). My treatment of vector identities is not to treat them as separate formulas to memorize or look up, but to work them out as needed during a derivation. This can be learned easily by students, and will be a valuable tool throughout their future work. The key is to understand the dual functions of the del vector operator, and never to neglect either function. This is drummed in in Section 1.6.

A professor may feel like skipping this section because most students have learned vector calculus. But, I have found that many students have been crippled by the way they learned it. I integrate dyadics into the vector operations. This enables a natural and straightforward treatment of dipoles, quadrupoles (static and in radiation), and the Maxwell stress tensor.

4. I have tried to include only problems that help with the understanding of, and application of, the concepts. I have tried to avoid problems with complicated algebra that do not serve any other purpose. I have not included many problems on new topics, not discussed in the text. You may want to add some problems in your field, but I have not tried to guess which topic you would want. I have not included many numerical calculations that are now possible with computers. I don't think much is learned about the concepts from extensive numerical work. I also have seen students spending too much time on perfecting computer calculations at the expense of learning concepts.

5. UNITS: I am aware that all UG texts are coerced into SI units. But the truth must be told that **E** and **B** are components of the same EM field tensor. This was developed 150 years ago by Maxwell's equations, and then conclusively required by Einstein and Minkowski. **E** and **B** can be put on the required equal footing only in Gaussian (or equivalent) units. Then Gaussian units lead naturally into natural units, with the

unification of space and time by Special Relativity.

A strong motive in the development of SI units was the mistaken notion that charge was a new dimension. This flies against all the developments of the last (20th) century, which have shown that all forces arise from gauge theories with dimensionless couplings. A dimensional coupling is meaningless, but is the root of MKSA SI.

One more polemic: epsilon naught and mu naught are not properties of free space, but of the mismatch of units. They have as much physical meaning as the fundamental constants 5,280 or 2.54. Graduate EM can only be developed to its natural conclusion in Gaussian units, followed by the relativistic realization that the number c appears only because the equivalent coordinates x and t had been given different units. Jackson's 3rd edition shows that a text cannot exist half slave and half free.

The Table of Contents is traditional (except for chapter 16) because Classical EM is a well defined theory. Most texts follow Maxwell's comprehensive orchestration, with Einstein's coda as the final movement. I feel there are a number of specific things that I have treated with a new perspective in an EM text. Some are:

Sec. 1.4.2: Gauss's law for Newton's gravitation.
Sec. 1.6: Coordinate independent definition of Del, and its operations.
Sec. 2.1: The organization of conductor properties.
Sec. 2.3.3: The treatment of electric dipole singularities (and magnetic dipoles in Sec. 7.11).
Sec. 2.4: Dyadic treatment of static quadrupoles (with radiation in Sec. 13.10).
Sec. 3.4: The Surface Greens Function treatment.
Chapt. 5: A concise, but comprehensive development of Greens functions.
Sec. 6.1-3: The treatment of the connection between E, P, and D.
Sec. 6.2: Clear definitions of the properties of permittivity (and permeability in Sec. 8.2).
Sec. 6.5: The Van der Waals force.
Sec. 7.10: Emphasis on the magnetic scalar potential.
Sec. 7.11 : Extensive development of the magnetic dipole moment.
Sec. 8.4-6: A different treatment of ferromagnetism than I have seen in other texts.
Sec. 8.7-8: The use of H in the electrostatic analogy for ferromagnets.
Sec. 9.4-5: A new treatment of EM energy, including the energy content of the polarization ($\mathbf{P}$) and magnetization ($\mathbf{M}$) fields.
Sec. 9.6-7: A clear delineation of EM field momentum and the use of the Maxwell stress tensor. It is shown that the two different forms of the EM momentum vector (each with its corresponding Maxwell stress tensor) apply to two different situations. This resolves the so-called Abraham-Minkowski controversy.

Sec. 11.1-2: A concise discussion of EM waves in conductors.
Sec. 11.5-6: A simple, but sufficient, treatment of
the dispersion of wave packets.
Sec. 12.2.4: Side by side comparison of TE and TM modes.
Sec. 13.4: The development of the effective radiation current $\mathcal{J}$.
Chapt. 14: The physical basis of relativity, and the meaning of
'Lorentz contraction', 'time dilation', 'E = mc2'.
Sec. 15.3.2: An understanding of the Trouton-Noble experiment.
Sec. 16.2: Electromagnetism as a Gauge Theory.
Sec. 16.3: The unification of EM with Weak and
(maybe) Strong Interactions.
Sec. 16.4: The relation between Classical Electromagnetism
and Quantum Electrodynamics.
Sec. 16.5 Natural units for EM consistent with unification.

Please feel free to email me at jerry.f@temple.edu if you have any questions or comments about my book. Jerry Franklin