Chapter 1

Introduction

1.1 Background to Course

The accepted approach to a graduate level E&M course is to work diligently through Jackson [Jackson 1999]. Since this is the first of two semesters, this course will cover the first half of Jackson. The problem with that approach is that most of you have already learned all the physics that is contained there and the difficulty of Jackson is the need for skill using special mathematical techniques to solve the problems. You have also been exposed to most of these mathematical techniques in earlier E&M courses or in other Math Physics courses or a Quantum Mechanics course. Particularly in the first half of Jackson, there are few concepts and little real physics. This is not a course in applied math and yet that is what a great deal of energy would be devoted to. The other problem with Jackson is that much of the effort is engaged in the details of the calculations not the clarification of the underlying physics. In this course, the emphasis will be on these basic interpretational and conceptual foundations that emerged as the understanding of electromagnetic phenomena was articulated. The skills developed in a Jackson course are necessary and they cannot be omitted from the training of physicists. In addition, at a certain point, when the subject is a compilation of techniques, it becomes crashingly dull. It's good for you but not fun.

The fact of the matter is that the classical theory of electricity and magnetism is an incredibly wonderful construction that is also the basis of our current approach to our understanding of everything. The requirement of local causality is at the heart of our understanding of the basic machinery that controls the behavior of matter and energy. In this course, I will em-

phasize this approach to Electricity and Magnetism. We will introduce the idea of the local field and with it the implications of local causality and the general properties of a dynamic based on partial differential equations by studying the one field that is introduced in every elementary physics course, the massive string under tension. This system is studied to develop an intuition and the vocabulary and mechanisms relevant to field theories. Students that are well versed in the mechanics of the string can skip this material although there is little harm in reviewing it. The electromagnetic field is then introduced intuitively and Maxwell's equations are presented. Then we get down to the serious business of the electromagnetic field theory starting with an extended review of the source free case, the theory of radiation. Instead of using the partial differential equations to control the interpretation of the dynamics, we will endow the field with mechanical properties. This will be accomplished by using action as the underlying principle of mechanics. The use of action will provide a unifying approach to all of the important aspects of the field properties. This approach also has the advantage that it manifests the fundamental role of symmetry in the formulation of physical laws and is the currently accepted approach to a quantum field theory. This is followed by an analysis of the important properties of the electromagnetic field system and the nature of its interactions. An important historical point is the theory of the classical electron. We conclude with a brief introduction to the modern quantum field theory and QED. In addition, there are some ideas from outside E&M that are important and usually not covered adequately in all undergraduate curricula and not detailed by Jackson such as action, Fourier transforms, and group theory. These are covered in appendices.

What about the stuff in Jackson? It constitutes half the course. We will do it in parallel with the more conceptual material through self study and reading and problem assignments. The other principle source for the other half of the course is these notes, lectures derived from them, and a weekly set of homework problems based on the lectures.