However, I will nearly *always* try to answer questions if/when you catch me. That doesn't mean that I will know the answers, of course ...

I welcome feedback and suggestions at any time during the year. I would prefer to hear constructive suggestions early so that I have time to implement them this semester.

1.6 The Interplay of Physics and Mathematics

Before we begin, it is worth making one very important remark that can guide a student as they try to make sense of the many, many things developed in this work. As you go through this material, there will be a *strong* tendency to view it all as being nothing but mathematics. For example, we'll spend a *lot* of time studying the wave (partial differential) equation, Green's functions, and the like. This will "feel like" mathematics. This in turn inspires students to at least initially view every homework problem, every class derivation, as being just another piece of algebra.

This is a *bad* way to view it. Don't do this. This is a *physics* course, and the difference between physics and abstract mathematics is that physics *means* something, and the mathematics used in physics is always *grounded in physical law*. This means that solving the very difficult problems assigned throughout the semester, understanding the lectures and notes, developing a conceptual understanding of the *physics* involves a number of mental actions, not just one, and requires your whole brain, not just the symbolic sequential reasoning portions of your left brain.

To develop *insight* as well as problem solving skills, you need to be able to:

- *Visualize* what's going on. Electrodynamics is incredibly geometric. Visualization and spatiotemporal relationships are all *right* brain functions and transcend and guide the parsed logic of the left brain.

- *Care* about what's going on. You are (presumably) graduate students *interested* in physics, and this is some of the coolest physics ever discovered. Even better, it is cool *and* accessible; you *can* master it completely if you care to and work hard on it this semester. Be *engaged* in class, *participate* in classroom discussions, show *intiative* in your group studies outside of the classroom. Maybe I suck as an instructor – fine, so what? *You* are in charge of your own learning at this point, I'm just the 'facilitator' of a process you could pursue on your own.

- *Recognize* the division between *physics* and *mathematics* and *geometry* in the problem you're working on! This is the most difficult step for most students to achieve.

Most students, alas, will try to solve problems as if they were math problems and not use any physical intuition, geometric visualization, or (most important) *the fundamental physical relationships* upon which the solution is founded. Consequently they'll often start it using some physics, and then try to bull their way through the algebra, not realizing that at they need to add *more* physics from *different* relations at various points on the way through that algebra. This happens, in fact, starting with a student's first introductory physics class when they try to solve a loop-the-loop problem using *only* an expression for centripetal force, perhaps with Newton's laws, but ignore the fact that energy is conserved too. In electrodynamics it more often comes from e.g. starting with the wave equation (correctly) but failing to *re-insert* individual Maxwell equations into the reasoning process, failing to use e.g. charge conservation, failing to recognize a physical constraint.

After a long time and many tries (especially with Jackson problems, which are notorious for this) a student will often reach the perfect level of utter frustration and stop, scratch their head a bit, and decide to stop just doing math and try using a bit of *physics*, and half a page later the problem is solved. This *is* a valuable learning experience, but it is in some sense maximally painful. This short section is designed to help you at minimize that pain to at least some extent.

In the following text some small effort will be made on occasion to differentiate the "mathy" parts of a demonstration or derivation from the "physicsy" parts, so you can see where physics is being injected into a math result to obtain a new understanding, a new constraint or condition on an otherwise general solution, the next critical step on the true path to a desired solution to a problem. Students might well benefit from marking up their texts or notes as they go along in the same way.

What part of what you are writing down is "just math" (and hence something you can reasonably expect your math skills to carry you through later if need be) and what part is *physics* and relies on your knowledge of physical laws, visualizable physical relationships, and intuition? Think about that as you proceed through this text.