A START ON A STRUCTURE FOR OUR WORKSHOP: GROUP 3

16 April 2007

Questions to address:

1. What is the "intermediate" level? What general background in physics should we assume? I am not sure we would all give the same answer to these questions, but we may have to agree on answers, at least for the purpose of the WORKshop.
2. Is it as hard to exploit computers usefully in E and M as Jan has suggested? Is visualization the primary objective in that subject area?
3. What is the broad nature of the module (or modules) we will construct? Are we thinking of modules that would be simply homework problems or modules that would be used as in-class demonstrations or, as Michael has suggested in his outline, broader modules that would include not only guidance for the lecture discussion and but also suggested homework exercises?
4. What are the relative merits of various tools (computer algebra software like MAPLE and MATHEMATICA; array processing programs like MATLAB and IDL; detailed coding in C or C++, JAVA, FORTRAN, VPython; visualization software of various sorts)? Do we want to advocate any particular tool? Or should we try to develop flexible modules that could be addressed with any one of several tools?
5. How are students—and faculty members, for that matter—to learn about the tools in a way that is effective and adequately comprehensive without detracting from the physics that is to be learned by employing the tools?
6. How do we make sure that incorporating computing will enhance the educational experience with minimal sacrifice in the development of important analytic knowledge and/or skills? This question is perhaps also tied to a question about the extent to which we are using computers on the one hand to support the teaching of physics and on the other hand to train students in the computational techniques *per se*. Probably we should come to some tentative conclusions about the balance between these two dimensions.
7. At what point does it make sense to exploit high performance computing, access to large remote data sets, and other such resources in our pedagogy—and how in broad terms might that exploitation be structured?
8. What should be the balance between exercises that can be done analytically but that provide a basis for developing confidence in the computational methods and exercises that can be done only computationally and that reveal the power of the fundamental ideas to deal with difficult and analytically intractable problems?
9. How can we make sure modules alert students to the pitfalls of doing arithmetic to finite precision? … to ways to assess computational error and keep it under control?

Components of a module:

Michael's email of a couple of days ago provides a good start on the broad outline that we might imagine a module aimed at providing not only background in classes but also homework exercises. Embellishing Michael's structure and picking up on several things you all have said in your emails, I suggest that modules should contain at least some of the following components.

1. Statement of purpose, including both the pedagogic objective and the physics to be learned. This statement should, among other things, help instructors determine where in a particular course the module would be appropriate.
2. Timeframe, i.e., how much in- and out-of-class time should be devoted to completing the module.
3. Assumptions, i.e., what background does the module assume the student *and the instructor* will bring to the module—and some guidance as to how that background might be obtained (if absent). For example, the module should provide references to be studied prior to attempting the module at hand. With full development, modules might point to prerequisite modules—which leads me to suggest that *some* modules might focus on the tools more than the physics. Perhaps we should give some thought to creating a suite of modules, one of which satisfies the ultimate objective (e.g., to develop appreciation for the properties of vector fields) and others of which might provide the background needed to attack the ultimate module.
4. Guidance for what to do in class, including particularly computer-based demonstrations or illustrations and discussion of assessment and control of error.
5. Identification in some detail of one or more homework exercises, including assessment and control of error.
6. For the instructor, full solution of the exercises with several different tools.

Suggested topics for modules: (Forgive me for not crediting specific individuals, but I think all of us have thoughts about topics that might have been explicitly mentioned by only one of us and in some cases I have shortened the list by merging similar topics suggested by different individuals.)

1. Model a classical H atom, even though it could technically fall under the classical mechanics category, either as a simple exercise to get started or as a review of something already done, in particular, the simple application of the first-order Runge-Kutta method and learning to develop some programming savvy (or the nuances of a particular commercial software package).
2. Model a classical He atom.
3. Visualization of any number of electric and magnetic fields and electrostatic potentials—though visualization of a particular field might also be preceded by determining the field (analytically or by numerical integration) from its sources. To be sure, if we want to focus on the visualization, we could simply provide the

field by giving a file of a described structure or by giving the corresponding analytic formula. Possible sources include a single charged disk or ring, a pair of parallel charged disks or rings, a solenoid, one or more current loops, a complicated charge or current distribution, ….

4. Solve Laplace's equation numerically (introduce the Jacobi method, or some similar relaxation approach for solving a partial differential equation) for a particular boundary geometry, and then create a 3D visualization of the resulting equipotential lines and field.
5. Solve Poisson's equation for a particular charge distribution and set of boundaries, and then do the associated visualization.
6. For any of the field visualizations, show also that the basic theorems (Gauss's law, Faraday's law, …) are satisfied by the field; determine and graph the charge distribution induced on boundaries; ….
7. Solve the equation for the trajectory of a particle in a prescribed field and then examine the trajectory graphically. The trajectory in the Coulomb field (item 1 above) and—my favorite—the trajectory in crossed constant E and B are two possibilities. Maybe a module could help students explore trajectories in quadrupole fields, such as those used to help guide beams in particle accelerators.