ELECTRICITY & MAGNETISM REFLECTIONS
on **Matter & Interactions II** course taught by Bruce Sherwood at NCSU in fall semester 2006.

Here are some revealing comments posted to the course forum by high school physics teachers in the Fall 2006 distance learning version of **Matter & Interactions II** (E&M). These are mature learners who are also articulate, and they are in a position to compare the **Matter & Interactions** instruction with the traditional intro course they had in college. The notes are in chronological order.

Teacher #1 (about what happens in the real world, as opposed to the oversimplifications in the traditional curriculum): “Sometimes I wonder if delving deeper into a course is a good thing! I was somewhat content with my knowledge of e&m before the course started. However, some aspects of the course have challenged what I know and how I think about e&m. I never thought of a charged piece of tape as a being polarized, with a field dependence other than r^2. I also learned (from my first physics course) that when an object is grounded, e- travel from a negatively charged object, thorough the body, into the ground. Learning what actually happens has given me "growing pains." When I think about situations where an object is discharged, I naturally want to go back to my prior picture of how this works, instead of what I know now to be the truth. It's going to take some time for the learning I've done in class to fully "sink in" and become comfortable. In a nutshell, learning that the world is a complex place is a bit scary. I'm the type of person that likes answers. I know as both a teacher and student that the more you learn, the more you realize you don't know. This can be quite unsettling!”

Teacher #2 (on the M&I detailed instruction on setting up integrals starting from a physical situation): “The method chosen to introduce potential, starting from constant E, then breaking it up into pieces, then into an infinite number of pieces, really makes sense and I think is a great way to teach the topic. I recall seeing line integrals as an introduction and never getting the principle down - it was too mathematical (and abstract at that with calculus) at the start and did not show simpler examples first, like Ruth does on the video. So now I get it. The one thing that I like conceptually that was not mentioned is that the word "potential" begs the question of "potential for what or to do what?" and I like the connection with "the potential to do work on something else" due to its being at some "potential". I see that in your approach you go right to the changes in potential between two places and so you did not need to focus on the meaning of the word at some single location.”

Teacher #3 (about the Biot-Savart law): “I can honestly say that until now I have never understood the Biot-Savart law. After going through the explanation in our C/S test I went back to look at the Halliday and Resnick approach I once tried to learn from. They never even apply the B-S law to a moving particle, jumping right to a current carrying wire. Their equations are:

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2} \text{ and } d\vec{B} = \frac{\mu_0}{4\pi}\frac{idl\times\vec{r}}{r^3}$$

I never understood how to use it, where did the r^3 come from? Why didn’t they say it was $Q\vec{v}\times\hat{r}/r^2$ (which they never even mentioned for a charge) and $Id\vec{l}\times\hat{r}/r^2$. Knowing what a unit vector is and using that in the step by step approach that Bruce and Ruth use in their text has been so enlightening. It really isn’t that different than using Coulombs law to solve for electric fields, but I didn’t connect the two approaches at all. I think I could teach this to students now, and feel comfortable explaining it. Thank you!”

Teacher #1 (about a lab in which they measured the magnetic field of a long straight wire, using a compass as the field detector): “I enjoyed this weeks lab activity (even though it was a bit difficult to do on my own; I had to enlist my wife to help!). I never remember playing with a compass and wires when I was in college physics; I just learned the theory (which was difficult, since I did not have any hands-on expereince to relate back to). Doing this activity helps reinforce the first right-hand rule, which was a big abstraction for me in my college physics classes. I remember memorizing the hand rules, which would be quickly forgotten after an exam. Doing this activity in lab and seeing the review problems in the lecture helped solidify this hand rule for me.

This is a good reminder for me in my classroom. When I get to magnetism, it is late in the year, and I am rushing to cover the rest of the curriculum. I tend to skip the hands-on experiences and just cover the content. However, doing this lab reminded me of how important the hands-on experiences are with magnetism. Seeing the rules in action is really helpful when it comes time to practice problems in homework or on a test.”

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Editorial comments on Teacher #1’s reflection: He has touched on an important piece of our own philosophy about the role of labs. To us the most important thing is to vivify the theory. Integrating to get the field of a long wire is pretty dead knowledge if you've never actually seen the magnetic field near a wire, and how "long" is long enough, and what about the right hand, and all that real-world stuff. A corollary, given limited time and the need to choose and prioritize, is that in the intro course we've chosen to downgrade detailed error analysis and long writeups. The cost-benefit ratio is unfavorable. Our labs tend to be experiential "minilabs".

Concerning sequence of topics, we deliberately introduce magnetic field as soon as possible, to give time for its meaning to sink in, and to offer many opportunities to compare and contrast electric and magnetic fields. Also, magnetic field forces a strenghened understanding of the field concept: source charges make field, field affects other charges. With electric forces, you can kind of get by just thinking about the Coulomb force law, and not really use the field concept at all. But the magnetic force that one charge exerts on another involves two cross products (one to make the field, another for the effect on another moving charge), and you can't write down a simple formula for the force, which makes you appreciate and better understand the concept of field.

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Teacher #3: I think what we are studying now are some really "neat" concepts. Two and a half years ago during a discussion on circuits, a colleague handed me the yellow version of the Chabay and Sherwood’s Matter & Interactions E&M text and said I should read chapter 18. For me it was an epiphany. I knew that the current in a series circuit was the same everywhere but had no mechanism to explain why. With my students the only explanation I could offer was “That’s how it is.” or “Somehow it knows.” The two points that made it all clear to me were what we are now studying. 1. The harder it is for the charge to get through a conductor the stronger the electric field needs to be to keep the charge flow constant, and 2. Uneven surface charge distributions cause the electric fields necessary for the circuits to achieve steady state. For me, those concepts are the most eye opening I have picked up in the last two and one half years. Learning this is the reason I decided to take this course. I figured if I could learn something that “neat” from their book, there was much more to be learned. I was correct.

One thing I don't understand is why these concepts are not more widely publicized. They explain so much, but I have not seen them in any other text.

Teacher #1: I find it interesting that I never remember hearing or thinking about the transient state before. I struggled in my E&M course in college. It was filled with lots of facts and equations that did not make sense at that time. It was a high paced class, so I had to learna lot of equations used to analyze circuits, etc... I don't remember having to give any thought to how circuits worked.

Since I didn't have a good understanding of the basics, I did not give any thought to higher level questions, such as the transition state fo circuits. I find this really interesting. Electric circuits aren't as simple as I once thought! There are a few milliseconds (or less) where there is a great deal of "complcated physics" happening. I find it humorous that I used to think I knew all that I needed to know about simple dc circuits...

Teacher #4: Same here. The M&I viewpoint is forcing me to ask and answer some questions that I've never really thought of before.

Teacher #3: It has been quite interesting to study circuit behavior from the point of view of the electric field. For us that studied (and have taught)fields in the equilibrium section of electricity and then rarely heard of them in circuits, this is quite a change. It makes a lot more sense to explain current from the point of view of an electric field, the area of the conductor and the mobility than using the rather abstract concept of resistance. Have my fellow students noticed that the word resistance has not even been used yet? I know when I studied physics in high school and college that I could not conceptualize how adding resistors could allow more current through the circuit. If I had learned that we are talking about conductors with different numbers of mobile electrons because of the area of the conductor, different mobilities of the charges inside and different electric fields because of their lengths, I might have had fewer years of puzzlement. Hopefully I will spare my students the confusion. The simple little lab with the nichrome wire perfectly illustrates the relationships of the electric field, area, length, potential difference and the current.

Teacher #1: I do find what you say interesting, and I haven't thought about it until now (the fact that resistors haven't been mentioned in the introduction to circuits)! I also learned about (and have taught) electric fields only in the static electricity unit. There was never any connection for me (or my students) after this unit. I believe this makes the abstract concept of electric fields even more difficult to present, since it comes and goes in about two weeks (the amount of time I spend reviewing static electricity with my students).

I also find it interesting that this information isn't in the mainstream yet (as mentioned in the previous thread). It would be so simple to make the connection about why electric circuits actually work, instead of just saying a battery provides a constant current. Hopefully in the future, the "physics world" will undergo some positive change...

Teacher #3: It has struck me how M&I approaches Faraday's Law compared to the approach used by the traditional texts (HRW, Serway, etc). In those textbooks the production of a "curly" (term not even used by them) electric field by a changing magnetic flux is introduced long after the production of an emf due to to the change. I now realize that approach often hides from a student what is really happening. If it was hidden from me, it certainly hidden from most of them. I need to make them see that the reason a current is produced is because an electric field is produced and the emf is simply the summation of E dot dL. The traditional texts have the cart before the horse. This spring I plan to change how I teach Faraday's Law. The field produced will be emphasized first since that is the mechanism, not a byproduct of an emf.