Workshop 8

PHY142: Honors Introductory E&M

12-04-2013

Topics: Electromotive force, Kirchoff's laws, energy in circuits, RC circuits, Magnetostatics: BS Law, steady currents, divergence and curl of $\mathbf{B}$.

1. Magnetostatics is a topic that allows us to describe the forces between charges in motion. What is the definition of the magnetic force in terms of a charge, Q, velocity, $\mathbf{v}$, and magnetic field, $\mathbf{B}$?
   - Using this definition stated above, and that for a charge Q moving an amount $d\mathbf{l} = \mathbf{v}dt$, determine the work done by the magnetic field.
   - What you arrive at might surprise you. Ultimately what this result tells us is that the magnetic field can alter the direction by which a particle moves, but cannot speed up or slow down Q. What agency controls work in magnetostatics?
2. Using the expression for force above we describe a force that couples the magnetic and electric fields. The *law of* _____________ allows us to write the Lorentz force law, which is...
   - Now it is clear that we can develop some analogs between electrostatics and magnetism. In Magnetostatics, we have a constant $\mathbf{B}$, implying the existence of a steady current. In Electrostatics, we have a constant $\mathbf{E}$, implying the existence of stationary charges.
   - In Electrostatics we have Coulomb's law to help us solve for the electric field. However if we have pleasant symmetry, it seems wiser to use Gauss's law. What are the analogs to these techniques in Magnetostatics?
3. Let's play with an infinite straight wire with its current coming out of the page. Sketch the magnetic field about this wire. Now let's calculate it!
   - Knowing that $B = \frac{\mu_0 I}{2\pi s}$ is the magnitude of the magnetic field, $\mathbf{B}$ around a circular path of radius s, centered at a wire – define a line integral of $\mathbf{B}$ around this closed path.

- Noticed that this answer is independent of s. Why do you suppose that is?
- Previously you should have hopefully derived some form of Ampére's law. Suppose now that we have a bundle of straight wires. Each wire that passes through our loop contributes $\mu_0 I$, while those outside contribute nothing. What will the line integral be now? What does this expression remind you of when considering electrostatics instead of steady currents?
- Now you should know three of Maxwell's equations. You might know the fourth, but write down the ones you know for good measure. What are their names? What do they mean?

4. Which problem would you use Ampére's law and which one would you use the Biot-Savart Law? Can you use both? Justify why. You don't need to solve them, but you can if you want.

   - Find the magnetic field a distance z above the center of a circular loop of radius R, which carries a steady current I.
   - Find the magnetic field a distance s from a long straight wire, carrying a steady current I.

5. So like Gauss's law, Ampére's law is always true (for steady currents), however not all situations call for it. When symmetry allows you to pull B out of the line integral, we can calculate the magnetic field using this technique. When it does work, it is super fast and effective. However when it doesn't you need to fall back on Biot-Savart Law. Think of four current configurations that can be handled by Ampére's law.