PHGN 462 Homework 1 – Due Wednesday August 28th

1) a) Let's start with an infinite 1-D wire of with some steady current I running through it. Write down the magnetic field it makes.

b) Now calculate the energy contained in that magnetic field. Or, more precisely, calculate the energy per meter of wire, since it's an infinite wire.

c) If you did it right, something should have gone terribly, terribly wrong in part b, owing to the fact that a 1-D wire is not an entirely realistic model of a wire. This happens sometimes. Models work until you push on them too hard, and then they break. Now model the wire as having some finite radius a, as wires generally do. Does that fix it? Comment one way or the other.

d) Now find the energy contained in the electric field of an electron.

e) You probably got something divergent again, if you tried to treat an electron as a point object. The thing is, an actual observed electron (as opposed to the wavefunction describing where it might be) *is* a radius-zero point, as far as we can tell. But there *are* error bars on that zero. Read up on what we know about the size of an electron, and see if you can fix things so that you can get a finite result for the electron's field energy. Go ahead and plug in numbers, too, to make sure this doesn't generate something absurd like 10^{100} Joules or something.

Note: Self-energies are notoriously tricky things. Infinities show up a lot and, frankly, it can be hard to get rid of them. See for example the whole notion of renormalization in quantum field theory.

2) Pollack and Stump 10.34. Also explain how to come up with that given differential equation, and derive the analytic steady-state solution for Q(t), either with Mathematica (show the code), or by hand. Write it in terms of ω_0, the resonance frequency for an LC or RLC circuit. As an easy check, you can make sure your solution reproduces eqn. 10.33 in the book when R goes to zero.

3) I think by now everyone has seen a Tesla coil. And, as it turns out, we now know enough to completely understand their operation. The most common design is basically a couple transformers and a capacitor (later designs involve vacuum tubes and transistors and such, but let's not worry about those).

Sketch out a design for a Tesla coil that'll make foot-long sparks when plugged into a standard 120V 60Hz wall outlet. Tell me what kind of inductors, capacitors, transformers, etc need to go in there, in which arrangement. I'd like a schematic and also a description of the parts and why they're there.

I'm deliberately leaving this rather open. It's a design task. That's kind of how those are. But correspondingly, I invite you to look up whatever you want in books or on the internet or wherever. Just get it done and tell me how.