Electricity Mash-up

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1. Find the force between two parallel nonconducting wires each of length ℓ, charge density λ, and separation distance s. The easiest way I see of doing this is to use two length parameters, one for each wire, then doing a double integral over both.

2. Mr. Schafer is going to assign this problem to you at some point but never grade it, so we are going to do an extension of the problem. Model the hydrogen atom like an electric charge distribution described by a point charge of magnitude e (proton) surrounded by a distribution of negative charge whose density is given by $\rho(r) = -Ce^{\frac{2r}{a}}$. We have C is a constant given to make the total charge e. What is the electric field inside a sphere of radius a?

   Remark. *From our knowledge of quantum mechanics, we know that the wave function for ground state hydrogen is* $\psi_{100}(r, \theta, \phi) = \frac{1}{\sqrt{\pi a^3}} e^{\frac{-r}{a}}$*, where a is the Bohr radius which is the most probable distance between the proton and electron in a hydrogen atom in its ground state. You should see a correspondence between the charge density equation and the wave function. Discuss what this might mean physically or ask me to explain why this problem is awesome.*

3. Consider two spherical clouds with the same amount of charge but different signs. So there is a positive cloud and a negative cloud. Both clouds have the same radius r and mass m. The two clouds are pulled towards each other by the Coulomb force and they overlap. The maximum speed upon overlapping is v. Find the magnitude of the maximum acceleration.

   Remark. *This problem is very tricky*

4. In a square of side length a, we place positrons and protons, alternating positron and proton starting from the top left corner, going clockwise. The positrons will fly off with some velocity v_e and the protons will fly of with some velocity v_p. Determine the ratio $\frac{v_p}{v_e}$. Take that the mass of a proton is 2000 times that of a positron.