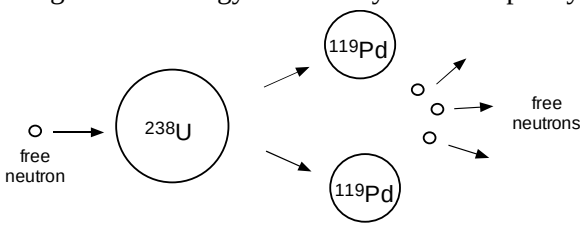
Reading Assignment:

Cheng: Sections 4.1-4.5
Schey: review material as needed

Homework #3 Due: Friday 16 October 2009

1) Do problem P.3-41 in Cheng.

2) The nucleus of $^{238}\mathrm{U}$ can be modeled as a sphere of radius 7.4×10^{-13} cm and total charge $92q$. Nuclear fission of $^{238}\mathrm{U}$ is initiated by the absorption of a free neutron, causing the nucleus to become unstable and decompose into two fission products, each of which is a nucleus of $^{119}\mathrm{Pd}$ of radius 5.9×10^{-13} cm with half the charge of the original nucleus. In the process a few extra neutrons are released, which in the right circumstances can generate a chain reaction that releases a large amount of energy. Assuming that the energy released by fission is purely electrostatic in origin:



   a. Find the electrostatic energy of the $^{238}\mathrm{U}$ nucleus prior to fission. Treat the nucleus as a sphere of uniform charge density, and use the result in Example 3-22 of your book (also covered in lecture or discussion). There is little error in taking $Q = Zq$ in the energy expression, but it is more technically correct to use $Q^2 = Z(Z-1)q^2$ to exclude the proton self-energy terms.
   b. What is the total electrostatic energy *after* fission?
   c. From (a) and (b), what is the energy released in the fission of a single $^{238}\mathrm{U}$ nucleus? How much energy can be liberated from 1 gram of $^{238}\mathrm{U}$? (the number of atoms in one gram is Avogadro's number/atomic weight). Compare this with the energy required to light a typical 60 Watt light bulb for one hour.

   (Note: this problem is a LOT easier to solve using $E = mc^2$! The purpose here is to illustrate that this energy is largely electrostatic in origin.)

3) Using the energy-force relationships, find an expression for electrostatic pressure (force per unit area) on the outer conductor of a air-filled coaxial cable, assuming an inner radius of a, outer radius of b, and voltage V applied between the conductors.

4) Do problem P.4-6 in Cheng.

5) Do problem P.4-10 in Cheng. Assume that the earth is perfectly flat and use image theory to relate the physical problem to a simpler one with a known solution. However, you need to use your head here: how does the wire-ground capacitance relate to the wire-image capacitance?

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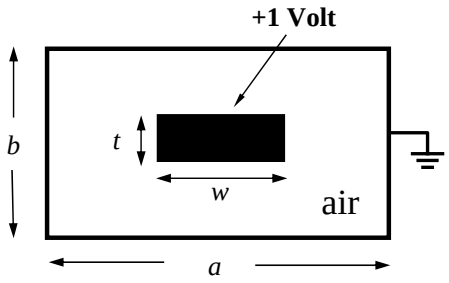
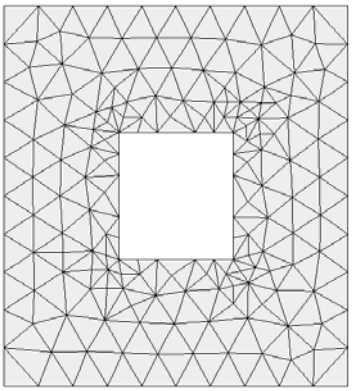
6) Consider the electrostatic problem with a hollow conducting tube at ground potential, and a solid conducting strip centered within the tube. This is similar to a coaxial line but with a rectangular cross section. In this problem assume $a = b = 3$ cm, $w = t = 1$ cm:



a. Using a numerical PDE solver such as FlexPDE, solve for the potential everywhere inside the structure for the specific boundary conditions shown. Hint: it is possible to solve this problem by defining two separate "REGIONS", but it is best to just define one region corresponding to the outer conducting boundary, and then define a second constant-voltage boundary inside this region for the inner conductor. You're on the right track if Flex shows a computational mesh like the one at right, which indicates that it isn't bothering to solve for the potential inside the inner conductor.



b. Calculate the capacitance per unit length of this structure in units of [F/m]. Apply some intelligent sanity checks here: just because the computer spits out a number doesn't imply that you set up the problem correctly! Also, be careful of units: if you specify all your dimensions in cm, for example,

Include the program script and a plot of the equipotentials for the problem if possible, with your name included somewhere in the plot and script as evidence of original work.