Homework Assignment Project #3, Due: Tuesday, 2/5/2017.

For this assignment... Understand electric potential energy, potential, and capacitance.

Submission Instructions: Submit to the grader's mailbox, on paper, your work done by hand. All problems must include a reasonable diagram.

1) Draw (in a 2D plane, by hand) the electric field lines and equipotential surfaces for:

- **a.** Two equal charges of $+Q$ separated by a distance of d.
- **b.** Two opposite charges of $+Q$ and $-Q$ separated by d.
- **c.** Carefully show (and/or state) *where* the electric potential is zero in these diagrams and explain, mathematically, *why*.

2) Through what potential difference must a proton pass to accelerate it from 10^4 m/s to 10^6 m/s? Repeat this problem for an electron.

3) Demonstrate the following sequence of derivations:

- **a.** The electric field **E** due to a point charge q, at some radius r, from Gauss's law.
- **b.** The electric potential difference between two radii a and b surrounding a point charge, by integrating the electric field **E**.
- **c.** The electric potential at a radius r from a point charge, relative to $V(r)=0$ at $r=\infty$.
- **d.** The vector electric field at a point r, derived from electric potential of a point charge.

4) A line charge λ that extends on the z-axis from $-a$ to $+a$. Find the electric potential at $\mathbf{r}=(2a, 0,0)$, assuming cylindrical or Cartesian coordinates, by integrating over the charge distribution (i.e., elements of dq').

5) Treating the earth as an isolated, spherical conductor, find its capacitance (noting that its potential can be defined relative to zero at an infinite radial distance). This is a very, very approximate result — "back of the envelope", neglecting the ionosphere.

6) … Now, let's not neglect the ionosphere: Assume that it forms a conducting layer at 75 km altitude above the Earths' surface. What is the capacitance of the Earth-ionosphere system?

7) A parallel plate capacitor is held at a fixed potential difference V. The plates are moved apart to double the distance between them, while maintaining the same potential.

- **a.** By what fraction does the capacitance C change?
- **b.** By what fraction does the total charge q on the capacitor plates change?
- **c.** By what fraction does the electric field E within the capacitor change?
- **d.** By what fraction does the stored energy U within the capacitor change?

8) Two capacitors are connected in parallel, and their combination is then connected in series with a third capacitor (for example, see Figure E24.20 in Young and Freedman, p. 812). The value of all capacitors are the same C, and they are held at a potential difference V.

- **a.** What is the equivalent capacitance of the whole system in terms of C?
- **b.** What fraction of the potential difference V is across the parallel combination of capacitors?
- **c.** What fraction of stored energy is within the parallel combination?
- **d.** Redo parts a, b, c for a case where the parallel capacitors (C_1, C_2) are 10 uF *each* and the capacitor in series with their combination (C_3) is 20 uF.

9) A "coaxial cable" (such as your household television cable) consists of "coaxial cylinders", containing a thin inner conducting cylinder with radius a, a cylindrical shell of insulating material (dielectric) from $a<r<b$, and an outer cylindrical conducting shell from $b \leq r \leq c$. Assuming that inner conductor has a charge per unit length λ (C/m) that is *distributed only on its surface,* and that the dielectric has the same permittivity as free space (ε_o), answer the following questions:

- **a.** Integrate the vector electric field to find the electric potential between a and b.
- **b.** Recall that capacitance is defined as $C=q/V$, find an expression for capacitance per unit length, $C_L=(q/L)/V$, in other words $C_L=\lambda/V$, for this cable.