Homework Week 5:

## Question 1. Pea sorting

It is possible to separate normal seeds from discolored ones (or foreign objects) by means of a device that operates as follows. The seeds drop one by one between a pair of photocells. If the color is wrong, a needle deposits a small charge on the seed. The seeds then fall between a pair of electrically charged plates that deflect the undesired ones into a separate bin. (One such machine can sort about 2 metric tons per 24 hour day!)

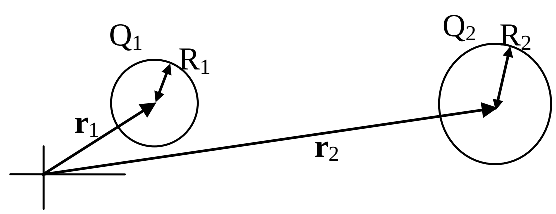
*Setup:* If 100 seeds fall per sec, over what distance must they fall if they are to be spaced vertically by 20 mm when they pass between the photocells? (Neglect air resistance.)
*Then:* Assume the seeds are about 1 gram, and acquire a charge of 1nC (that's nano, 1E-9), the deflecting plates are parallel and 1cm apart, and the potential difference between them is 10,000 volts. How far should the plates extend below the charging needle if the charged seeds must deflect by 45 mm after leaving the plates? (Assume the charging needle and the top of the deflecting plates are close to the photocell.)

## Question 2. Potential of infinitely long straight wire

CALCULATION (deGrand)
Find the electrostatic potential a distance $r$ from an infinitely long straight wire containing a uniform charge per unit length $\lambda$ by (a) integrating E (b) directly integrating the "standard formula" for V. In part (b) you will have to be very careful to compute a difference of potentials between two points, or something similar, to avoid integrals which are infinite!

## Question 3. Shells of charge

Two charged droplets of toner ink behave as two *shells* of uniform surface charge density. (Toner is an insulating material, not metal.) Shell 1 has total charge $Q_1$ , radius $R_1$, with its center at position $\mathbf{r}_1$. Shell 2 has $Q_2$ , $R_2$, and $\mathbf{r}_2$. Write expressions for the voltage V(**r**) everywhere: outside both spheres, inside sphere 1, and inside sphere 2. (Hint: use curly r notation, but define your symbols carefully.) Is the voltage inside shell 1 constant?




## Question 4. Calculate radius of electron 2

REAL WORLD; CALCULATION (Zimmerman, have solns)
*ELECTRON MASS 3*
The mass of an electron is $m_e = 9.11 \times 10^{-31}$ kg. The relativistic mass energy of an electron is $m_e c^2$. Given the apparent infinite electrostatic energy associated with a point charge, is is tempting (though wrong) to view the electron not as a point charge, but as a sphere of uniform charge density whose electrostatic energy is equal to the mass energy of an electron. What would the radius of such a ball of charge be? (The electron's charge, which has the special symbol *e*, is -1.60x10-19 coulombs).

**Question 5. Energy of cylindrical capacitor**

CALCULATION (deGrand)

Find the electrostatic energy per unit length stored in a long cylindrical capacitor (inner radius $a$, outer radius $b$) with a potential difference between the plates equal to V, in two ways: (a) Find C and use $W = \frac{1}{2} C V^2$. (b) Use $W = (\frac{\varepsilon_0}{2}) \int E^2 d^3x$: you must find and integrate E. In this part, finish by expressing the charge per unit length $\lambda$ in terms of V to show that you get the same answer in (b) that you got in (a).