Problem Set 2: Electrostatics, Capacitance, Current

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due before 3pm, 21 July 2008
3. Email submission: pleclair@ua.edu
4. Hard copies: Gallalee 206 or Bevill 228; at the *beginning* of the lab period.
5. You may collaborate, but everyone must turn in their own work

1. 10 points. (a) How much negative charge and how much positive charge are there on the electrons and the protons in a cup of water $(0.25\,\text{kg})$? Note Avogadro's number is $N_A = 6.022 \times 10^{23}$, and each oxygen atom has 8 electrons. **(b)** What is the magnitude of the attractive force exerted by the electrons in a cup of water on the protons in a second cup of water at a distance of $10\,\text{m}$?

2. 5 points. Consider two toner particles separated by $1.2 \times 10^{-5}\,\text{m}$; each of the two particles has a negative charge of $-30\,\text{fC}$. What is the electric force that one particle exerts on the other? Treat the toner particles approximately as point particles. Note that $1\,\text{fC} = 10^{-15}\,\text{fC}$.

3. 10 points. Eight equal charges q are located at the corners of a cube of side a. **(a)** Find the magnitude of the total force on one of the charges due to the other seven charges. **(b)** Find the electric potential at one corner, taking zero potential to be infinitely far away.

4. 10 points. An ion milling machine uses a beam of gallium ions $(m = 70\,\text{u})$ to carve microstructures from a target. A region of uniform electric field between parallel sheets of charge is used for precise control of the beam direction. Single ionized gallium atoms with initially horizontal velocity of $1.8 \times 10^4\,\text{m/s}$ enter a $2.0\,\text{cm}$-long region of uniform electric field which points vertically upward, as shown below. The ions are redirected by the field, and exit the region at the angle θ shown. If the field is set to a value of $E = 90\,\text{N/C}$, what is the exit angle θ?
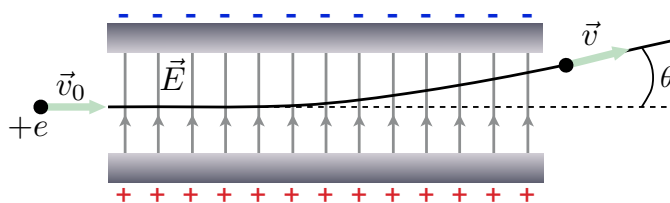

5. 5 points. A sphere the size of a basketball is charged to a potential of $-1000\,\text{V}$. About how many extra electrons are on it, per cm^2 of surface?

6. 15 points. In the circuit below, if R_0 is given, what value must the R_1 have for the equivalent resistance between the two terminals a and b to be R_0?
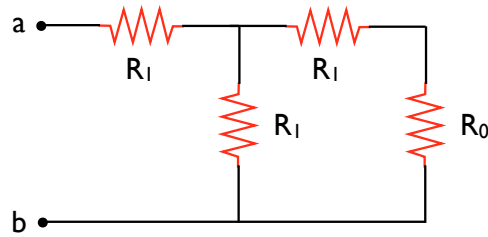
7. 10 points. The distance between the oxygen nucleus and each of the hydrogen nuclei in an H_2O molecule is 9.58×10^{-11} m, and the bond angle between hydrogen atoms is $105°$. **(a)** Find the electric field produced by the nuclear charges (positive charges) at the point P a distance 1.2×10^{-10} m to the right of the oxygen nucleus. **(b)** Find the electric potential at P.
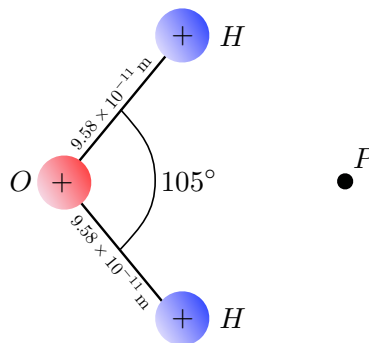
8. 15 points. Five identical point charges $+q$ are arranged in two different manners as shown below - in once case as a face-centered square, in the other as a regular pentagon. Find the potential energy of each system of charges, taking the zero of potential energy to be infinitely far away. Express your answer in terms of a constant times the energy of two charges $+q$ separated by a distance a.
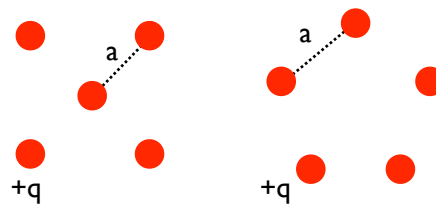
9. 10 points. You are given two batteries, one of $9\,\text{V}$ and internal resistance $0.50\,\Omega$, and another of $3\,\text{V}$ and internal resistance $0.40\,\Omega$. How must these batteries be connected to give the largest possible current through an external $0.30\,\Omega$ resistor? What is this current?

10. 10 points. Two capacitors, one charged and the other uncharged, are connected in parallel. **(a)** Prove that when equilibrium is reached, each carries a fraction of the initial charge equal to the ratio of its capacitance to the sum of the two capacitances. **(b)** Show that the final energy is less than the initial energy, and derive a formula for the difference in terms of the initial charge and the two capacitances.