University of Alabama
Department of Physics and Astronomy

PH 102-2 / LeClair Spring 2008

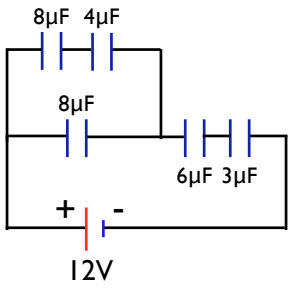
Problem Set 3: Electrical Energy & Capacitance

Instructions:

- Answer all questions below. Show your work for full credit.
- Due before 5pm, 1 Feb 2008
- Problem sets may turned in *via* email or hard copy
- Hard copies may be left in Dr. LeClair's mailbox (Gallalee 206) or office (Bevill 228)
- You may collaborate, but everyone must turn in their own work

1. 10 points. Remember #7 on last week's homework? Calculate the potential energy of that system of three charges, for a circle of radius r. Take the zero of potential energy to be infinitely far away from all charges. Express your answer in terms of the energy of charges q_1 and q_2 separated by r – *e.g.,* a constant times $k_e q_1 q_2 / r$.

2. 15 points. (a) Find the equivalent capacitance of the capacitors in the figure below. **(b)** Find the charge on each capacitor. **(c)** Find the potential difference across each capacitor.



3. 10 points. A parallel-plate capacitor has 4.00 cm^2 plates separated by 6.00 mm of air. If a 12.0 V battery is connected to this capacitor, how much energy does it store in Joules? In electron volts?

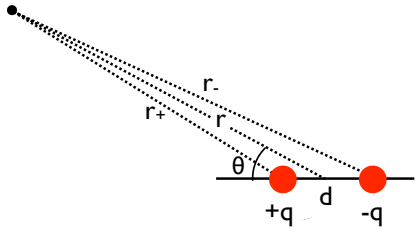
4. 5 points. A capacitor with air between its plates is charged to 150 V and then disconnected from the battery. When a piece of glass is placed between the plates, the voltage across the capacitor drops to 25 V. What is the dielectric constant of the glass? (Assume the glass completely fills the space between the plates.)

5. 10 points. A potential difference of 100 mV exists between the outer and inner surfaces of a cell membrane. The inner surface is negative relative to the outer. How much work is required to move a sodium ion Na^+ outside the cell from the interior? Answer in electron volts and Joules. A singly-charged ion has a charge of $1e$.

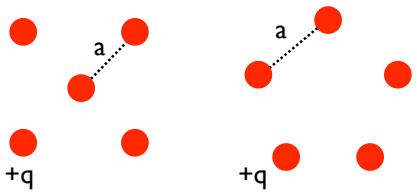
6. 5 points. A proton and an electron are accelerated from rest through a potential difference of 120 V. Calculate the speed and kinetic energy of each.

7. 5 points A parallel plate capacitor is held at constant voltage. Initially there is only air between the plates. If a dielectric with a dielectric constant of 2 is inserted into the capacitor, what happens to the energy stored in the capacitor?

8. 15 points. Two charges, $+q$ and $-q$, are separated by a distance d. Show that the electric potential far from both charges is approximately $V = \frac{kqd\cos\theta}{r^2}$. The following approximations may be useful (referring to the figure below, with the origin between the two charges): $r_- r_+ \approx r^2$, $r_- - r_+ \approx \frac{xd}{r} = d\cos\theta$.



9. 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. Bonus (3 points): could one make a two-dimensional repeating crystal with either of these arrangements? Justify your answer.



10. 10 points. If each of the charges in the pentagon arrangement above are $1\,\mu$C and $a = 1\,$m, what is the electric potential at the center of the pentagon? Again take the zero of potential energy infinitely far away.