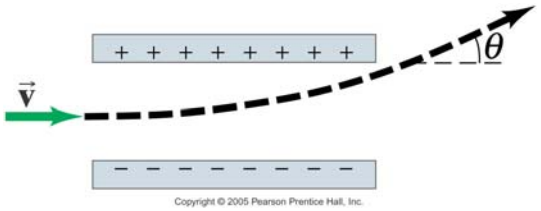
# Physics 111
# Fall 2007
# Electric Potential

1. A lightning flash transfers 4.0 C of charge and 4.2 MJ of energy to the Earth. (*a*) Across what potential difference did it travel? (*b*) How much water could this boil and vaporize, starting from room temperature?

2. In a television picture tube, electrons are accelerated by thousands of volts through a vacuum. If a television set were laid on its back, would electrons be able to move upward against the force of gravity? What potential difference, acting over a distance of 3.0 cm, would be needed to balance the downward force of gravity so that an electron would remain stationary? Assume that the electric field is uniform.

3. An electron is accelerated horizontally from rest in a television picture tube by a potential difference of 5500 V. It then passes between two horizontal plates 6.5 cm long and 1.3 cm apart that have a potential difference of 250 V, as shown below. At what angle $\theta$ will the electron be traveling after it passes between the plates?




4. In lightning storms, the potential difference between the Earth and the bottom of the thunderclouds can be as high as 35,000,000 V. The bottoms of the thunderclouds are typically 1500 m above the Earth, and can have an area of $110\ \text{km}^2$. Modeling the Earth-cloud system as a huge capacitor, calculate (*a*) the capacitance of the Earth-cloud system, (*b*) the charge stored in the "capacitor," and (*c*) the energy stored in the "capacitor."

5. Imagine assembling four equal charges one at a time and putting them at the corners of a square. Find the total work done to assemble these if the charges are each 5 μC and the square has 25 cm sides.

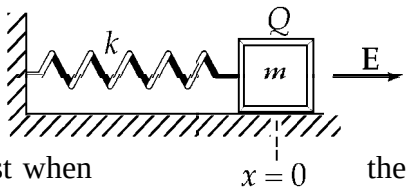
6. Equal and opposite ± 10 μC charges lie along the x-axis with the + charge at x = 0.1 m and the - charge at x = -0.1 m. Find a) the electric potential at the origin; b) the electric field at the origin; c) the work required to bring a third +10 μC charge from far away to the origin. Repeat all three parts if now all charges are +10 μC.

7. Suppose a biological membrane with a specific capacitance of 1 $\mu F/cm^2$ has a resting surface charge density of 0.1 $\mu C/cm^2$. Also suppose there are 50 sodium channels per $\mu m^2$ and that when each opens for 1 ms 1000 $Na^+$ ions flow through the channel. Find the membrane voltage 1 ms after 10% of these channels open, assuming no other changes occur during this time.

8. In a 100 $\mu m^2$ area of a muscle membrane having a density of sodium channels of 50 per $\mu m^2$ of surface area, when the sodium channels open there is a rapid flow of 1000 ions per channel across the membrane. Assuming a 100 mV resting potential, all the channels opening at once and a membrane capacitance of 1 $\mu F/cm^2$, find the voltage change across this area of membrane due solely to the sodium ion flow.

9. An air-spaced parallel-plate capacitor has an initial charge of 0.05 μC after being connected to a 10 V battery.
   a) What is the total energy stored between the plates of the capacitor?
   b) If the battery is disconnected and the plate separation is tripled to 0.3 mm, what is the electric field before and after the plate separation change?
   c) What is the final voltage across the plates and the final energy stored between the plates?
   d) Calculate the work done in pulling the plates apart. Does this fully account for the energy change in part (b)?

10. A 4 kg block carrying a charge of Q = 50 μC is connected to a spring for which k = 100 N/m. The block lies on a friction less horizontal track and the system is immersed in a uniform electric field of magnitude $5x10^5$ V/m directed as shown. If the block is released from rest when the spring is unstretched at x = 0m,



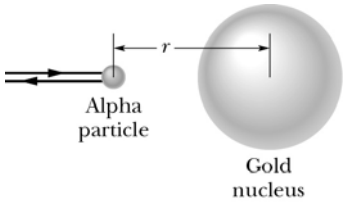

a) by what amount does the spring stretch?

b) What is the equilibrium position of the block?

c) Is the motion of the block simple harmonic?

d) Repeat part a) if the coefficient of kinetic friction between the block and the surface is 0.2.

11. An alpha particle (which contains 2 protons and 2 neutrons) passes through the region of electron orbits in a gold atom, moving directly toward the gold nucleus, which has 79 protons and 118 neutrons. The alpha particle slows and then comes to a momentary rest, at a center-to-center separation r = $9.23x10^{-15}$m before it begins to move back along its original path. (This technique is called *Rutherford Backscattering Spectroscopy* and the alpha particles are usually accelerated using a particle accelerator, like the one we have in the basement of Science and Engineering!)




a) What was the initial kinetic energy of the alpha particle when it was initially far away, external to the gold atom? (Hint: Assume that the gold atom does not move since it is much more massive than the alpha particle.)

b) Given the kinetic energy in part a), through what potential difference was the alpha particle accelerated?

c) How much work was done on the alpha particle in accelerating it through the potential difference in part b)?

d) The Union College Pelletron particle accelerator 1.1MV tandem electrostatic accelerator. When using this machine alpha particles are accelerated two times in succession (hence the tandem) and interact with the nucleus of a gold

atom. Supposing that the alpha particles reach an energy of 3.3MeV using the Pelletron accelerator, what will the center-to-center separation of the alpha particle and the gold nucleus?

12. The nucleus of a hydrogen atom consists of a single proto, which can be treated as a point charge.
    a) With the electric potential equal to zero at an infinite distance, what is the electric potential due to the proton at the electron's position, 0.53x10-10m away?
    b) What is the electric potential energy in electron volts, of an electron at the given distance away from the proton?
    c) If the electron moves farther from the proton (to a higher orbit) does the electric potential energy increase or decrease?