CH 17-2 – Electric Potential and Voltage

Important Ideas

- The electric potential V at a distance r from a charged particle is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

  For a positively charged particle, the potential V is positive and decreases for points further from the particle, going to zero at infinity. For a negatively charged particle, the potential V is negative and increases for points further from the particle, going to zero at infinity.

- Electric field always points toward lower potential V. Electric field points "downhill," in terms of the potential V. In one dimension

$$E_x = -\frac{\Delta V}{\Delta x}$$

  where E_x is the electric field between points Δx apart with a potential difference ΔV. On a graph of V vs. x, E_x is the slope.

  For a constant electric field, the potential difference between two points a distance d apart, along the direction of the electric field, is:

$$\Delta V = Ed$$

- The potential difference ΔV between two points in space is called *voltage* and one usually refers to the *voltage across two points*. A common application is in circuits where one might refer to the voltage across a capacitor or the voltage across a battery, for example.

- The potential energy of a system that includes a charged particle q that is at a location of potential V is

$$U = qV$$

- If a charged particle moves from a location with potential V_i to a location with potential V_f, then the change in the potential energy of the system is:

$$\Delta U = q\Delta V$$

  A convenient unit of energy is the electron-volt (eV). 1 eV = 1.6×10^{-19} J.

- A capacitor is used to create a uniform electric field. The electric field between the plates is

$$E = \frac{\Delta V}{d}$$

  where ΔV is the voltage across the plates and d is the distance between the plates.

- The charge on capacitor plates depends on the voltage across the plates. The proportionality constant is its capacitance C.

$$Q = C\Delta V$$

- The capacitance C depends on the area of the plates, the distance between the plates, and insulator between the plates.

$$C = \frac{\kappa \varepsilon_0 A}{d}$$

where κ is the dielectric constant. $\kappa = 1$ for a vacuum and is greater than 1 for all insulators.

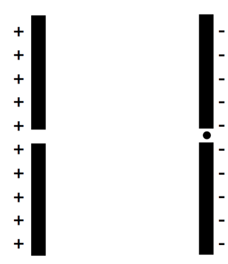
Examples

1. Two oppositely charged plates (called a capacitor) separated 2 cm are used to accelerate an electron. The electric field between the plates is 25,000 N/C. An electron is released from rest in a hole at the negatively charged plate.

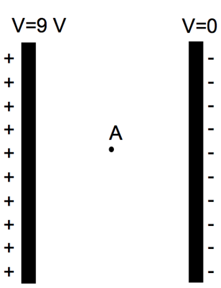
   (a) What is the voltage across the plates that produced the electric field?

   (b) As the electron travels across the plates, what is its change in potential energy in eV?

   (c) As the electron travels across the plates, what is its change in kinetic energy in eV?



2. What is the potential halfway between the plates of the capacitor shown below?



   (a) 9V

   (b) zero

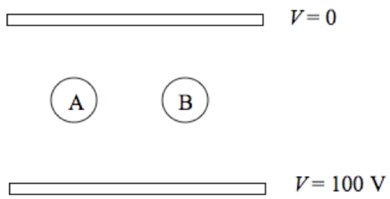
   (c) 4.5 V

   (d) 2.25 V

   (e) None of the above

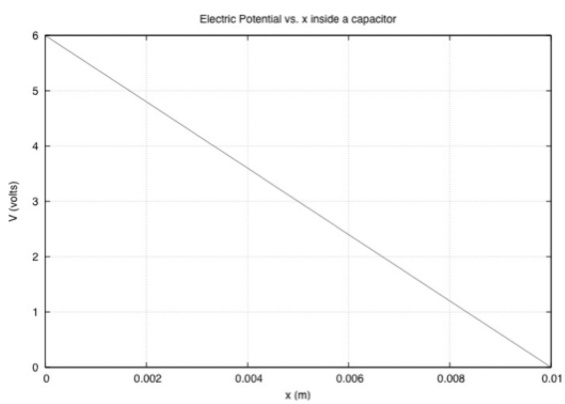
3. For the previous question, if the plates are separated a distance of 3 cm, how far from the 0 V plate is the potential 2.0 V?

4. If the molecules are negatively charged, toward which plate will they migrate?



(a) 0 V plate
(b) 100 V plate

5. What is the electric field inside the capacitor?



(a) -6 V/m
(b) -300 V/m
(c) 600 V/m
(d) 300 V/m
(e) -600 V/m

6. If you connect a 3.0 V battery across a 0.5 m long copper wire, what will be the electric field within the wire that causes current to flow through the wire?

(a) 1.5 V/m
(b) 6.0 V/m
(c) 3.0 V/m
(d) 2.5 V/m
(e) zero

7. If you connect 4 1.5-V batteries “in series” (with positive terminal of one battery connected to the negative terminal of another), what is the total potential difference across the negative terminal of the first battery to the positive terminal of the last battery?

8. If you connect a 1 μF capacitor to a 6-V battery. How much charge will be stored on each of the capacitor plates?

9. Suppose that a capacitor is made of two plates that are 1 cm x 5 cm in dimensions. They are separated a distance of 1 mm. What dielectric constant would you need in order to increase its capacitance by a factor of 10 and what would be the capacitance?