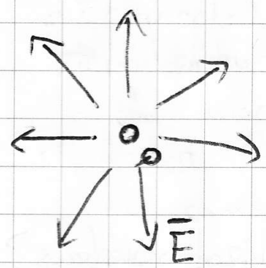
11/21/13

Equipotential Lines

- Consider the point charge discussed last class
  - $\bar{E}$ points radially outwards



$$E(r) = k\frac{Q}{r^2}$$

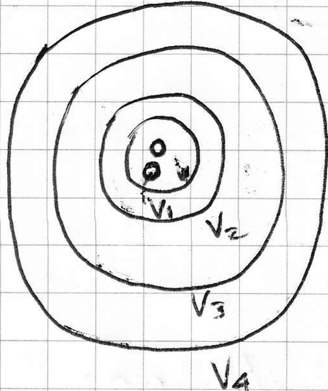
$$\bar{E}(\bar{r}) = k\frac{Q}{r^2}\hat{r} \quad \rightarrow \text{strength falls off as } 1/r^2$$

$$E(r) = -\frac{dV}{dr}$$ (E tells us how the potential changes w/ posit

$$\rightarrow V(r) = k\frac{Q}{r}$$ (separate variables and integrate!)

- 'equipotential lines' defined as lines where the potential is const.
  $\rightarrow$ $\bar{E}$ is perpendicular to them

- moving a test charge around such a line means no change in the kinetic energy (or potential energy)



- for a point charge, equipotential lines are coencentric circles

- $V_1 > V_2 > V_3 > V_4$ (if $Q>0$; the converse is true if $Q<0$)
  $\rightarrow$ make sure that this makes sense in terms of energy!

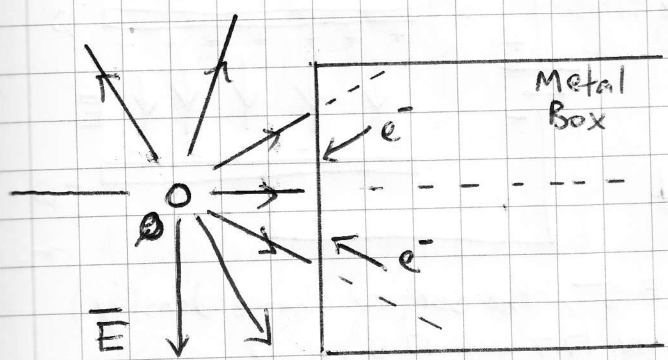
7/21/13

Electric Fields Near **Metals**

- What is a metal?
  → A lattice of atoms that can lose one (or more) electrons (making the atoms become positive ions). These free electrons can fairly easily move freely about the entire lattice, making the metal a good **conducting** material

[Note: this notion of a conductor is an important one that we will regularly revisit]

- The ability for charge to freely move about has a number of consequences for how the metal responds to and affects external electric fields

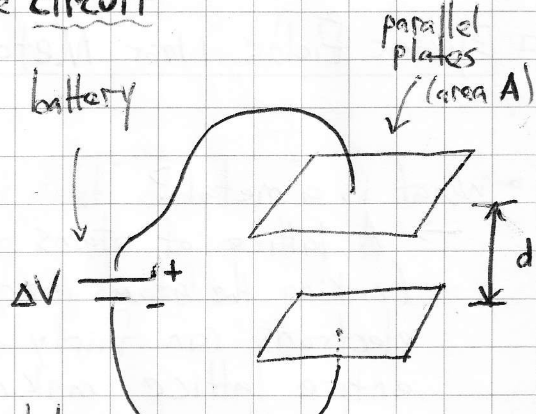


- Consider a point charge outside a metal box
  - $\bar{E} = 0$ inside box (!)
  - Why?
    → free electrons move to counteract the field (they want to be near Q!)

- Implications
  - Net charge on a conductor is on the surface
  - All places inside the box will have zero electric field due to external charge(s)
  - Very useful idea to help with electrical **shielding**
  - Electric potential is non-zero inside box

11/21/13 A simple circuit

Capacitance

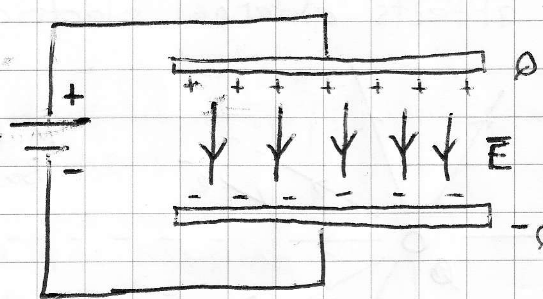


- Consider two parallel plates, (w/ area A, separated by fixed distance d) connected to a battery with voltage ΔV

1. charge will flow very briefly until the same potential difference (as that across the battery) is established across the plates

2. The positive battery terminal will 'suck electrons' off the top plate, while the negative terminal will 'push' electrons onto the bottom plate

3. So then how much charge (Q) will be displaced?



→ From earlier, we know that

$$E = \frac{Q}{\epsilon_0 A} \quad \left(\text{where } \frac{Q}{A} = \sigma, \text{ the surface charge density}\right)$$

(see Giordano ex. 17.7 and 17.8)

and that the potential difference across the gap is

$$\Delta V = Ed$$

then $\boxed{\Delta V = \frac{Q}{\epsilon_0 A} d = \frac{Q}{C} \quad \text{where } C = \frac{\epsilon_0 A}{d}}$

(we call this the **capacitance**)

- Note that C depends primarily upon the properties of the plate and thereby, for a fixed ΔV, dictates how big that displaced charge Q is

  1) Larger area A $\rightarrow$ bigger C $\rightarrow$ bigger Q
  2) Smaller separation d $\rightarrow$ bigger C $\rightarrow$ bigger Q
  3) change in ϵ_0? (we'll get there shortly when we consider **dielectrics**)

- Units for capacitance are farads ($1\,F = 1\,C/V$). As capacitance tends to be small in most electric circuits, a more common unit is $1\,\mu F$ (i.e. a microfarad $= 10^{-6}\,F$)

- Capacitors are one of the most common elements found in electric circuits (in addition to resistors and inductors)
  $\rightarrow$ this notion of a **circuit** is a key concept that we will develop for much of the rest of the semester

- A key way to think about capacitance is one of **energy storage** (for example, consider the potential energy associated w/ the normal force that keeps the plates at a fixed separation d despite the attractive force between them

$\boxed{ex}$ The dimensions of a parallel plate capacitor are all increased by a factor of three. How does the capacitance change?

$$C_1 = \frac{\epsilon_0 A}{d} = \frac{\epsilon_0 (L \times W)}{d}, \quad C_2 = \frac{\epsilon_0 A'}{d'} = \frac{\epsilon_0 (3L \times 3W)}{3d} = 3\epsilon_0 \frac{LW}{d} = 3C_1$$