March 3, 2013 Physics 132 Prof. E. F. Redish

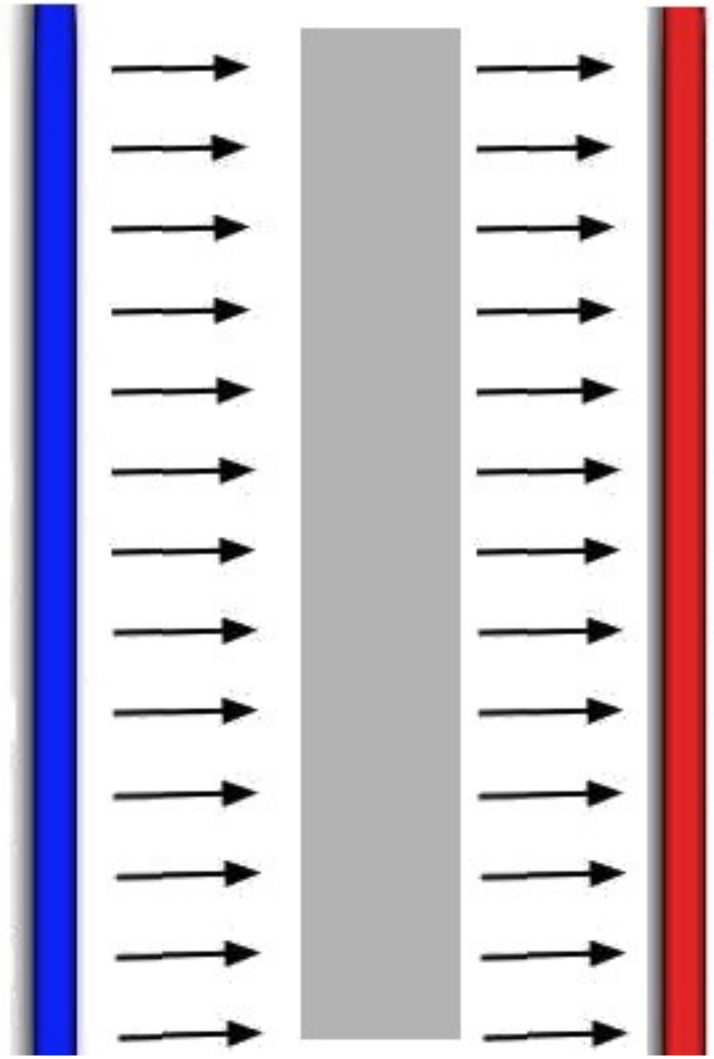
- **<u>Theme Music:</u> Bob Gramann**

  You're nothin' but a pack of neurons

- **<u>Cartoon:</u> Bill Watterson**

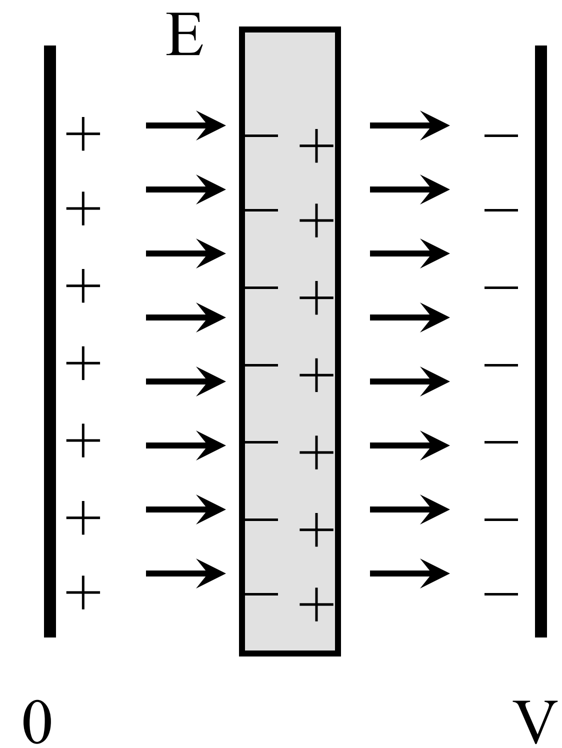
  Calvin & Hobbes

What happens
if I put
a conductor into
an electric field?



Consider what happens with a conductor

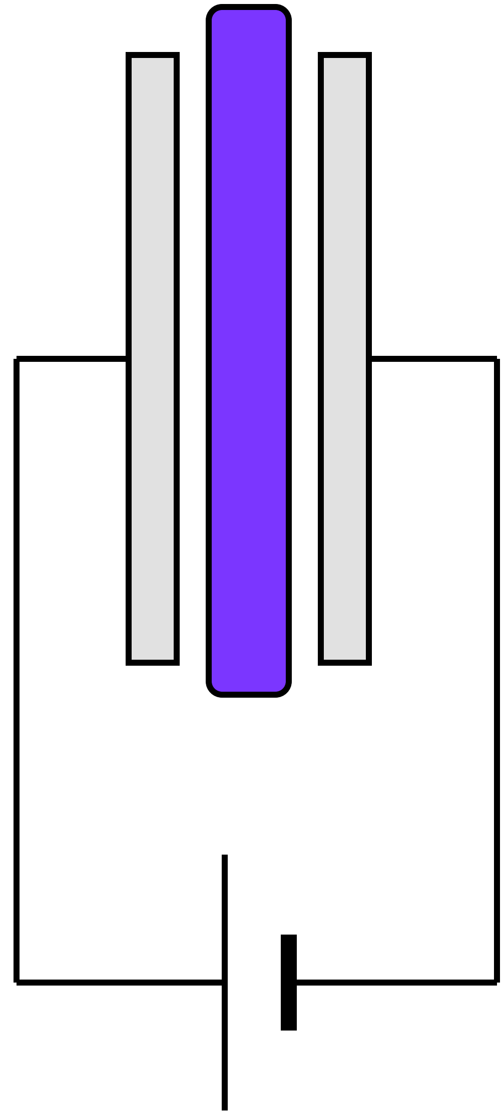
- The potential difference is produced by adding up $E\,\Delta s$.
- If we can reduce E along the path, we can reduce ΔV.
- Inside a static conductor, there can be no E field. (Why not?)
- What happens if we put a conducting sheet between the plates?



Conductors

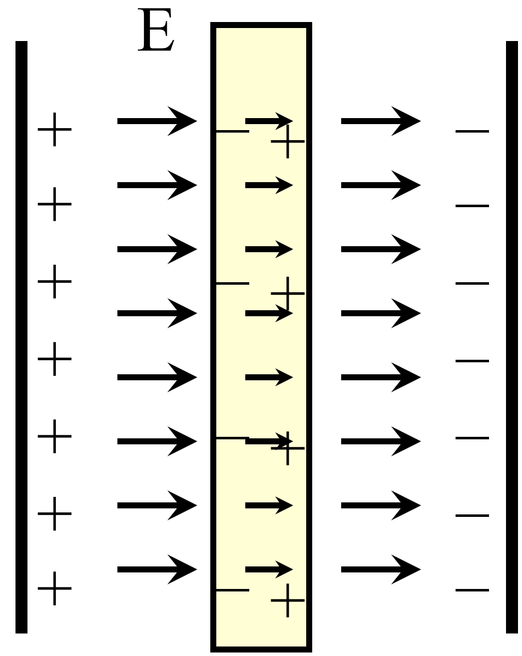
- Putting a conductor inside a capacitor eliminates the electric field inside the conductor.
- The distance, d', used to calculate the ΔV is only the place where there is an E field, so putting the conductor in reduces the ΔV for a given charge.

$$C = \frac{1}{4\pi k_C}\frac{A}{d'}$$



Consider what happens with an insulator

- We know that charges separate even with an insulator.
- This reduces the field inside the material, just not to 0.
- The field reduction factor is defined to be κ.



0

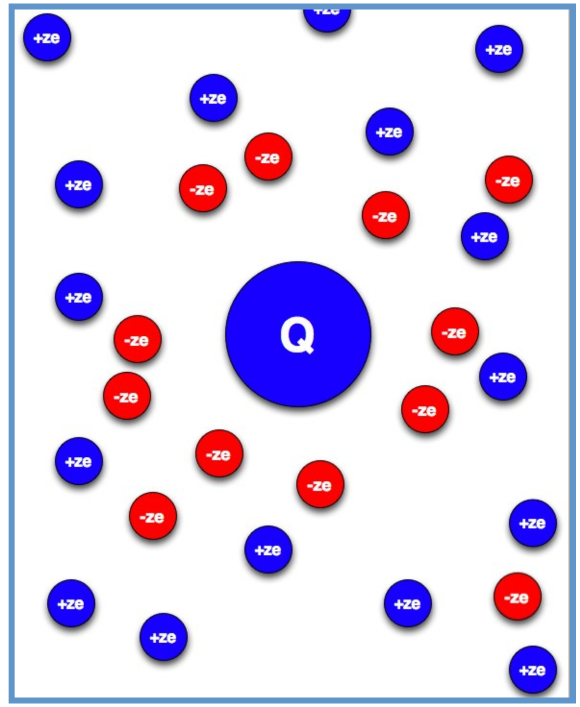
$$E_{\text{inside material}} = \frac{1}{\kappa} E_{\text{if no material were there}}$$

Foothold ideas: Electric charges in materials

- **Electroneutrality** – opposite charges in materials attract each other strongly. Pulling them apart to create a charge unbalance costs energy.
- If a charge is placed in an ionic solution, it tends to draw up ions of the opposite type and push away ones of the same type.
  - Result: the charge is **shielded**. As you get farther away from it the “apparent charge” gets less.
  - The scale over which this happens is called the **Debye length, λ_D.**

Debye length equations

- Charge imbedded in an ionic solution.
  - Ion charge = ze
  - Concentration = c_0
  - Temperature = T
  - Dielectric constant = κ
- The ion cloud cuts off the potential



$$\lambda_D = \sqrt{\frac{k_B T}{8\pi\left(\frac{k_C z^2 e^2}{\kappa}\right)c_0}} = \sqrt{\frac{k_B T}{2\left(\frac{z^2 e^2}{\kappa\varepsilon_0}\right)c_0}}$$

$$V(r) = \frac{k_C Q}{\kappa r} e^{-r/\lambda_D}$$

Foothold Ideas: Electric Current

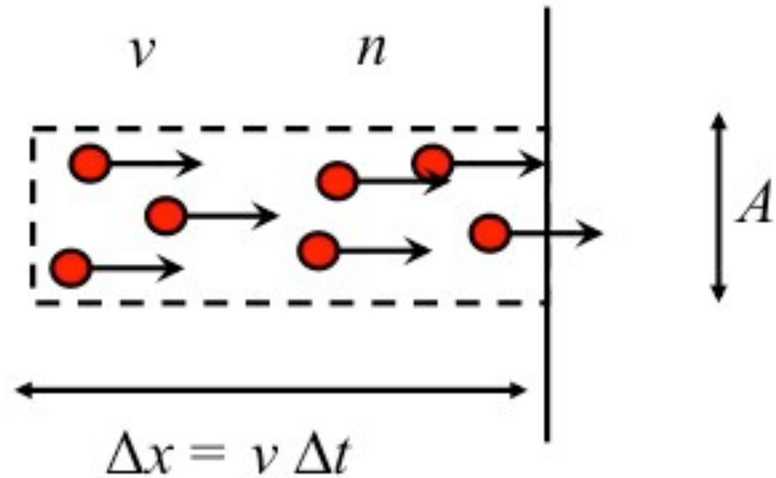
- Current is a measure of the motion of charge.
- The current is defined as the rate at which charge crosses a given surface.

$$I = \frac{\Delta q}{\Delta t}$$

- You can have current even in neutral matter if one kind of the charge is moving differently from the other.
- Unit of current: Ampere = Coulomb/second.
- Sign of current: We choose a direction as +. Current is + when + charges cross in the + direction.

Foothold Ideas: Current Density

- How much charge crosses an area A in a time Δt?
  - each moving charge has a charge, q
  - the density of moving charge per unit volume is n
  - the speed of the moving charges are v



- J = current density (current/unit area)

$$I = JA \qquad J = qnv$$

Moving Charges in a Neutral Conductor

- What happens if we arrange charges to put an electric force on a neutral conductor?
  - Positive ions are fixed in a lattice
  - Some negative charges (shared electrons) are free to move