Theme Music: Bob Gramann

You’re nothin’ but a pack of neurons

Cartoon: 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 $\Delta V$.
- 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 $\Delta V$ is only the place where there is an E field, so putting the conductor in reduces the $\Delta V$ 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 $\kappa$.

\[
E_{\text{inside material}} = \frac{1}{\kappa} E_{\text{if no material were there}}
\]
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, \( \lambda_D \).**
Debye length equations

- Charge imbedded in an ionic solution.
  - Ion charge = $ze$
  - Concentration = $c_0$
  - Temperature = $T$
  - Dielectric constant = $\kappa$

- 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.
- 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.

\[ I = \frac{\Delta q}{\Delta t} \]
Foothold Ideas: Current Density

How much charge crosses an area $A$ in a time $\Delta t$?

- each moving charge has a charge, $q$
- the density of moving charge per unit volume is $n$
- the speed of the moving charges are $\nu$

$J = \text{current density} \quad (\text{current/unit area})$

$I = JA \quad J = qnv$
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