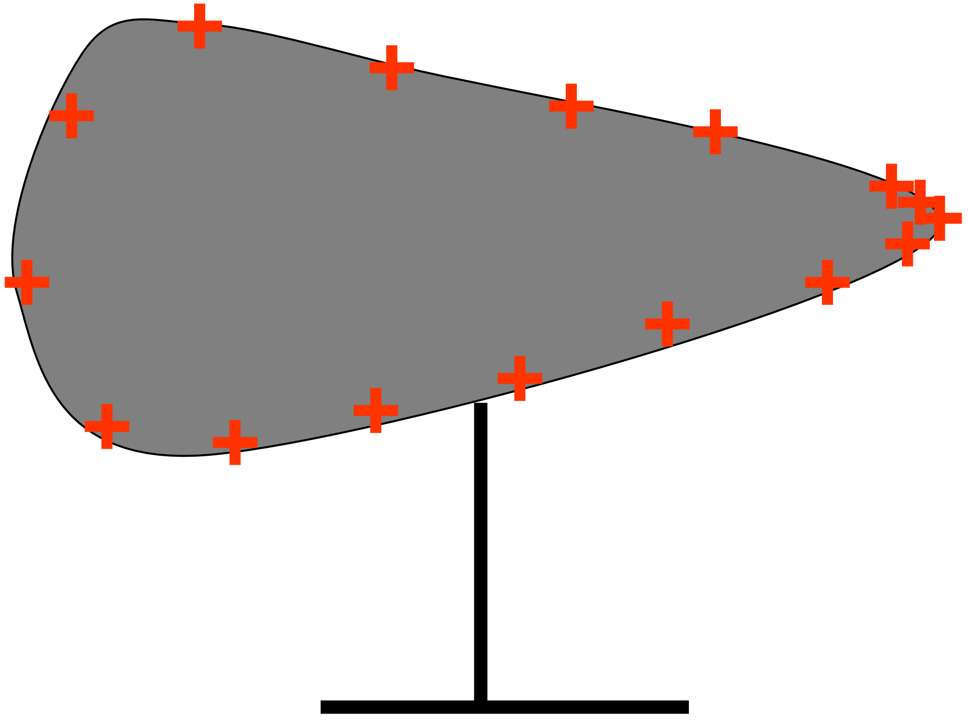
Electricity and Magnetism

- Electric Potential
  - Electric Field and Electric Potential
  - Capacitors

More on Electric Potential

- Where do charges go?



More on Electric Potential

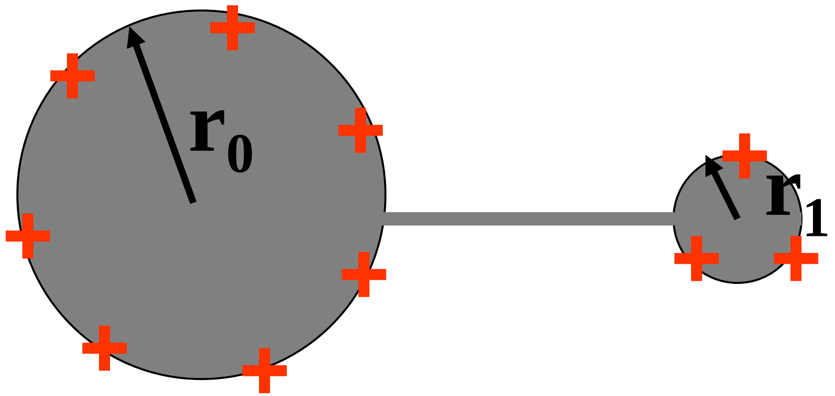
$$V_0 = \frac{Q_0}{4\pi\epsilon_0}\frac{1}{r_0} =$$

$$V_1 = \frac{Q_1}{4\pi\epsilon_0}\frac{1}{r_1}$$

$$\Rightarrow Q_0/r_0 = Q_1/r_1 = 4\pi\epsilon_0 V = \text{ const.}$$

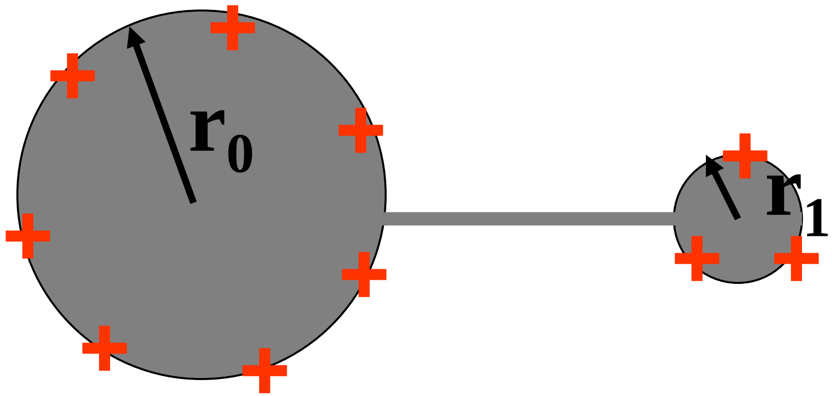
$$E_i = \frac{\sigma_i}{2\epsilon_0} = \frac{Q_i}{4\pi\epsilon_0 r_i^2}$$

$$\Rightarrow E \propto \frac{1}{r} \propto \sigma$$



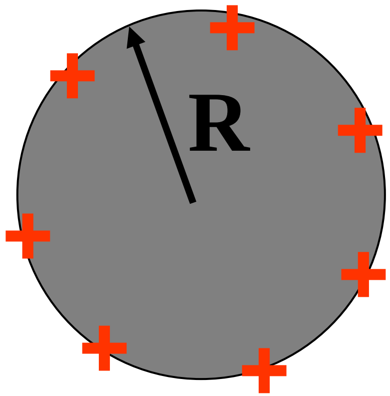
More on Electric Potential

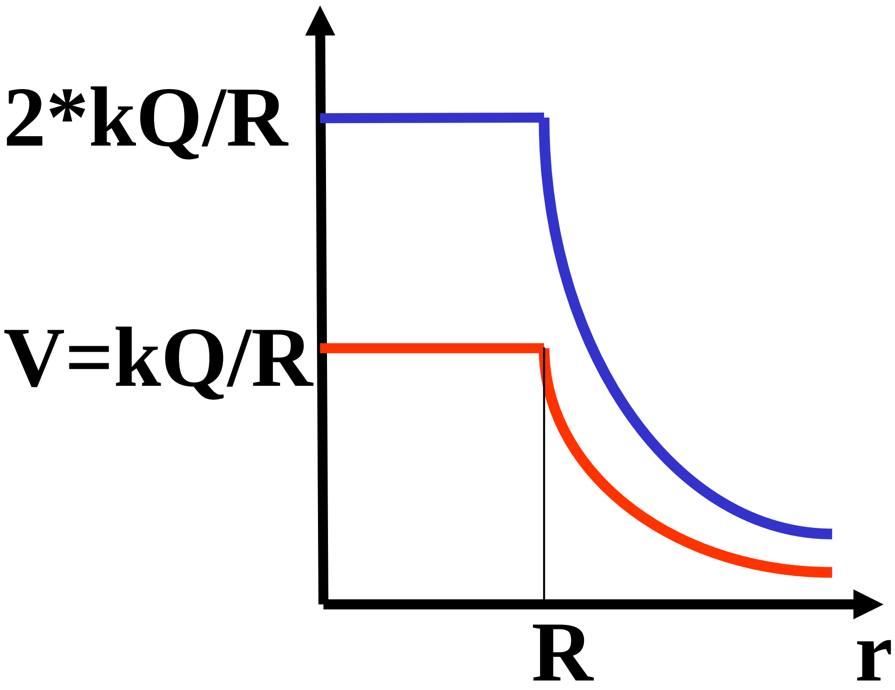
- Practical application
  - **Lightning rod: Pointy tip -> small r!**



Charge and Potential

- Potential is proportional to Charge





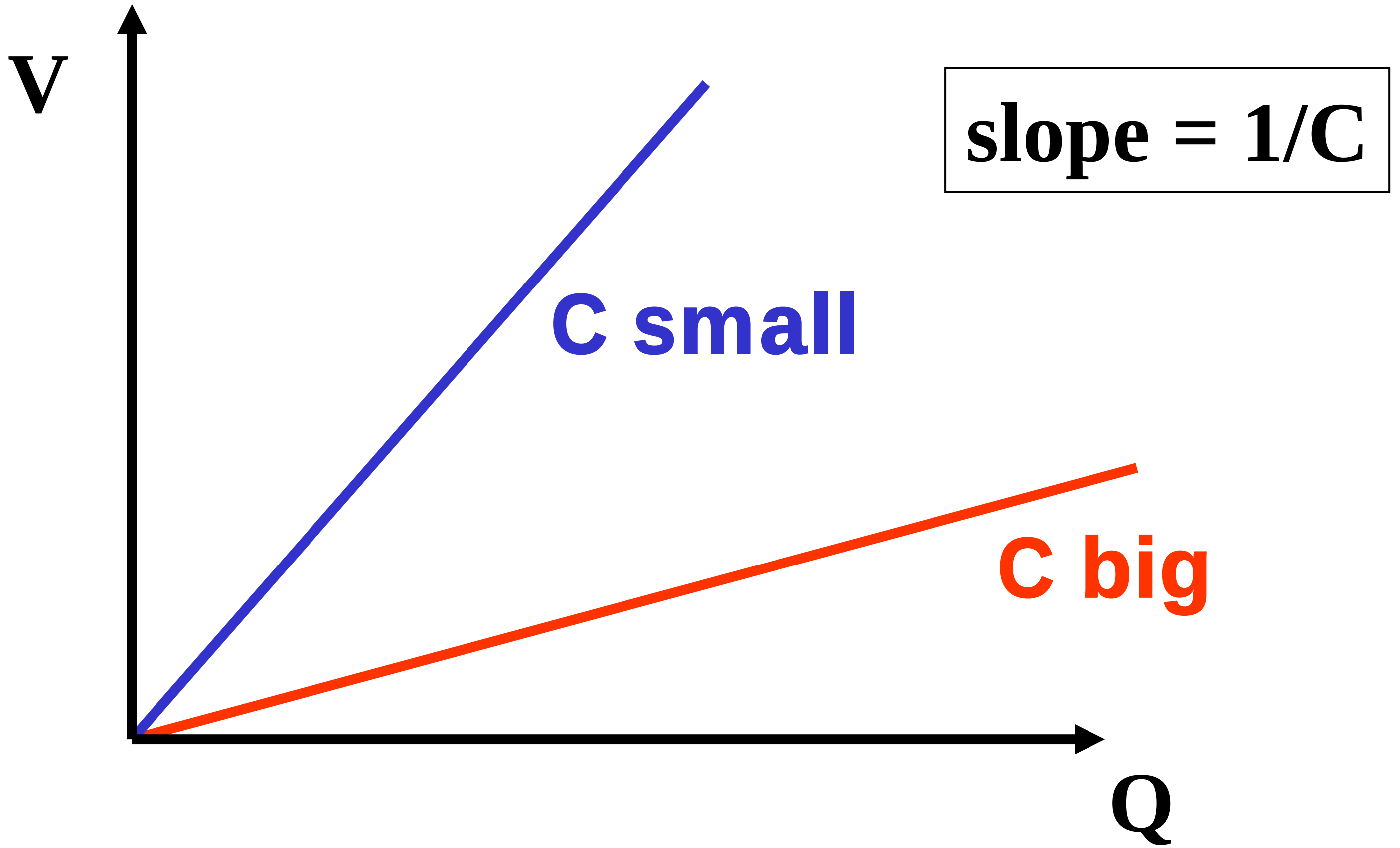
Charge and Potential

- Potential is proportional to Charge
  - **V * constant = Q**
- True for any object
  - true for point charge
  - Superposition principle
- Define
  - **Q = C V   -> C is called Capacitance**

Capacitance

- [Capacitance] = [C/V] = Farad
  - 1 Farad is huge
- Sphere
  - $C = R/k$
  - The bigger the sphere, the bigger the capacitance

Capacitance



Q = C*V => V = Q/C

Capacitance

- Example C(Earth):

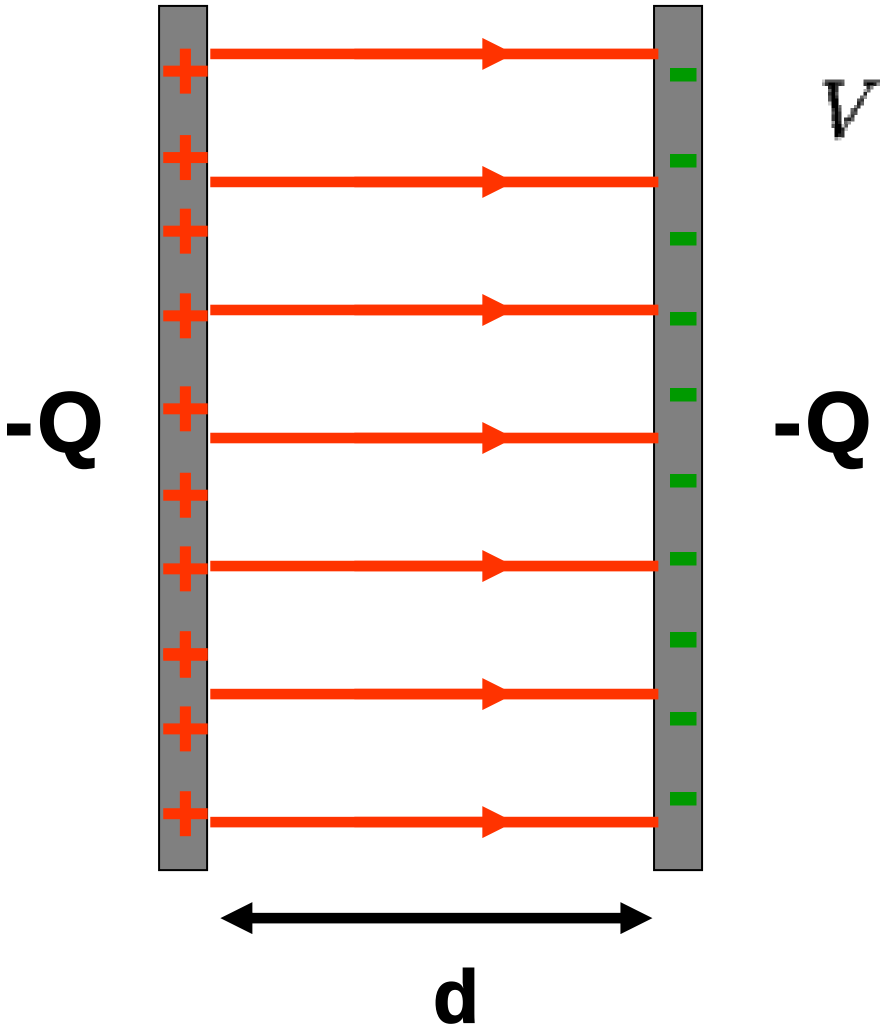
  $C = 6*10^6 m / 9*10^9 Nm^2/C^2 = 540 \mu Farad$

  - Small capacitance
  - Potential increases quickly with charge
  - Hard to put charge on sphere
  - For sphere, reference point is r=infinity
  - How to build better device?

Capacitor

- Better capacity
  - don’t get charges from infinity, but from other object close-by
- Capacitor
  - Def: Two conductors separated by insulator
- Example: Parallel plate capacitor

Parallel Plate Capacitor



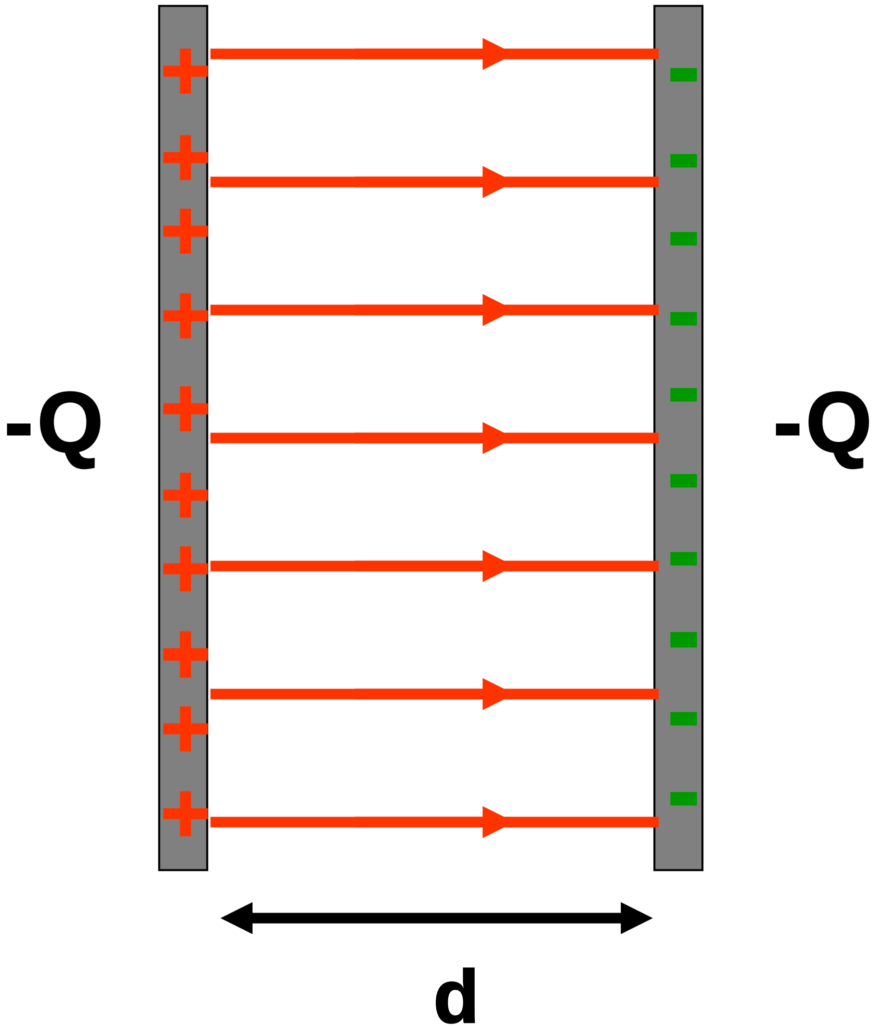
$$V(a) - V(b) = \int_a^b \vec{E} d\vec{l}$$
$$= E \int_a^b dl = E\ d$$

$$|E_{+,-}| = \frac{\sigma}{2\epsilon_0}$$

$$\sigma = Q/A$$

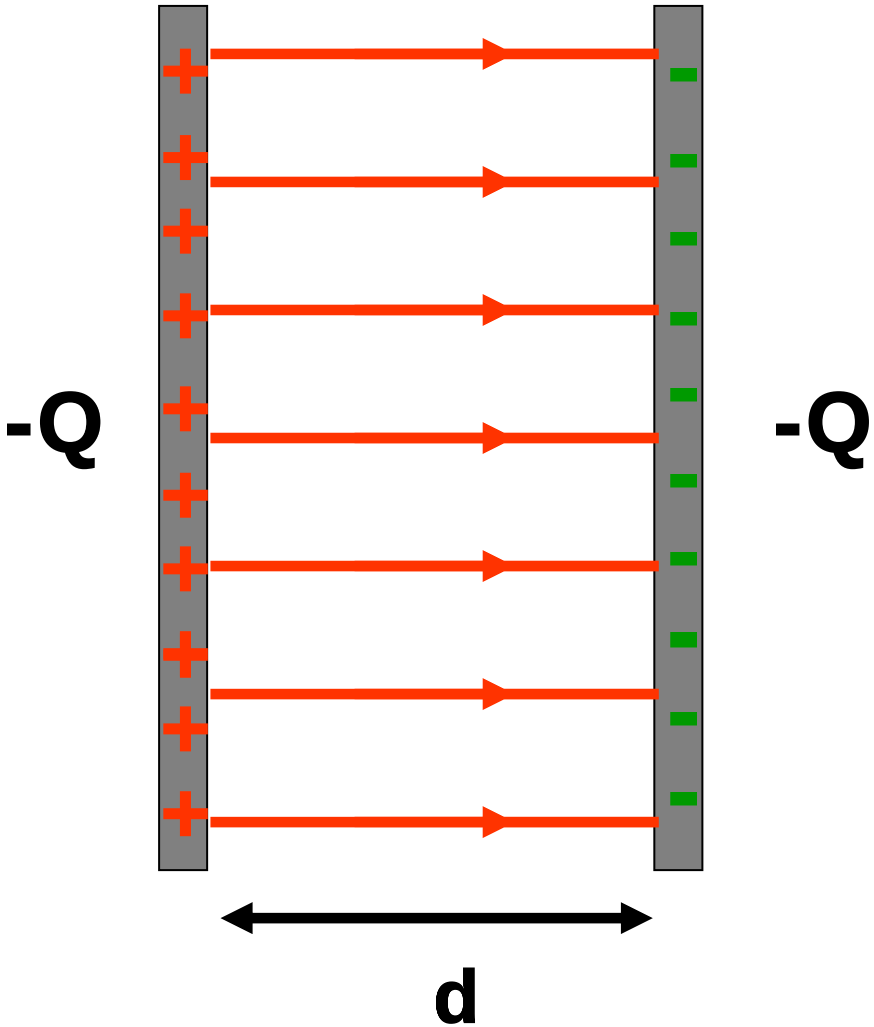
$$E_{center} = \vec{E}_+ + \vec{E}_- = \frac{\sigma}{\epsilon_0}$$

Parallel Plate Capacitor



$$
\begin{aligned}
C &= \frac{Q}{V(a) - V(b)} = \frac{Q}{E\,d} \\
&= \frac{Q}{\frac{\sigma}{\epsilon_0}\,d} = \frac{Q}{\frac{Q}{A\epsilon_0}\,d} = \\
&= \epsilon_0 \frac{A}{d}
\end{aligned}
$$

Parallel Plate Capacitor



$$C = \varepsilon_0 A / d$$

- Depends only on Geometry!
  - like it did for sphere
- To store lots of charge
  - make A big
  - make d small

Parallel Plate Capacitor