Chapter 2 Conductor & Dielectric

2.1 The Conductor in Electrostatic Field

2.2 Capacitance and Capacitor

2.3 Dielectrics in Electric Field

2.4 The Energy Storage in Electric Field

2.1 Conductor in Electrostatic Field

◈ Conductor: a material with free electrons

- Excellent conductors: metals such as Au, Ag, Cu, Al,...
- OK conductors: ionic solutions such as NaCl in H_2O

- Insulator: a material without free electrons
- Organic materials: rubber, plastic,...
- Inorganic materials: quartz, glass,...

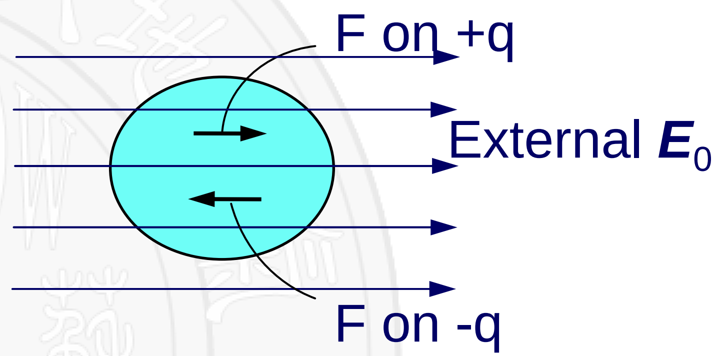
2.1 Conductor in Electrostatic Field

◈ The Conditions of Electrostatic Equilibrium

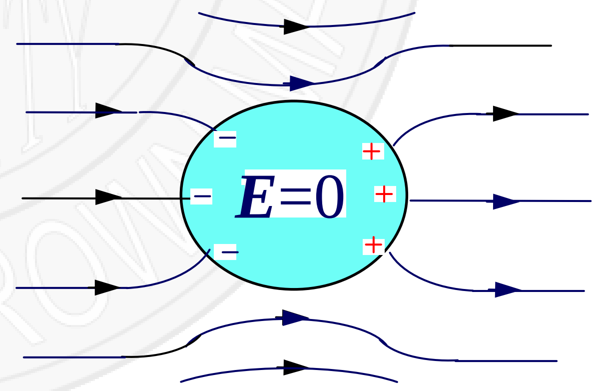
- Inexhaustible free charges
- Inside a conductor, **E**=0.
- Why?

If E≠0, migration doesn't stop.

- Finished in 10^{-17}-10^{-16}s



$$\vec{E} = \vec{E}_0 + \vec{E}'$$



2.1 Conductor in Electrostatic Field

◈ The Conditions of Electrostatic Equilibrium

- If there is no motion of charges (except thermal motion) in conductor, the state of the conductor is called electrostatic equilibrium.
- Electrostatic conditions is E=0 (everywhere inside).
- Electric potential inside a conductor is constant
- External field lines are perpendicular to surface
- Conductor’s surface is equipotential

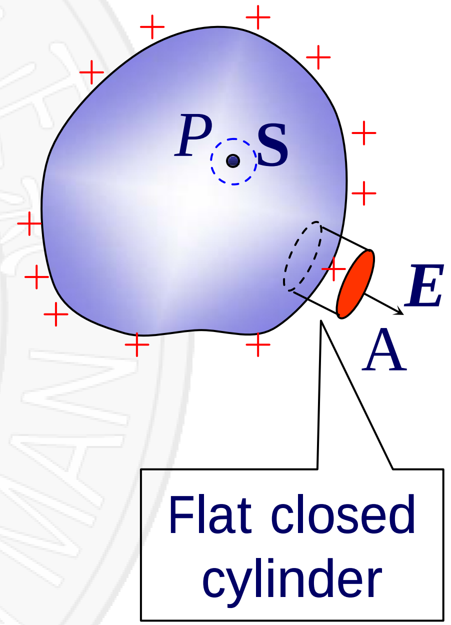
2.1 Conductor in Electrostatic Field

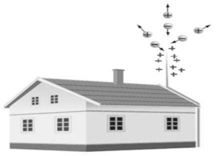
The Distribution of Charge on a Conductor

- Distribution of Charge
  - Inside conductor $\rho=0$ everywhere

    Gauss's Law
  - Net charge resides on the surface
  - σ will vary from point to point
- The Electric Field near Surface

$$E = \frac{\sigma}{\varepsilon_0}$$





2.1 Conductor in Electrostatic Field

The Distribution of Charge on a Conductor

- The Electric Field near Surface

$$E = \frac{\sigma}{\varepsilon_0}$$

Show Vander Graff and q

From OCW of mit

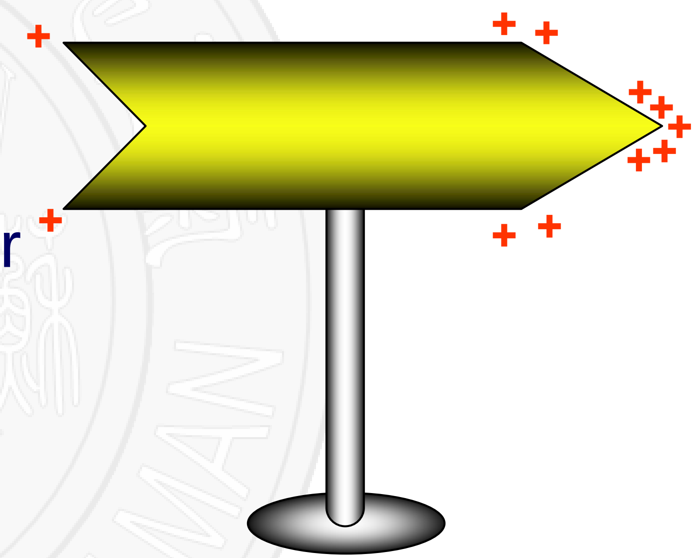
- The electric field ***E*** at points immediately above a charged surface is proportional to the charge density σ.

- The more density σ, the stronger field

2.1 Conductor in Electrostatic Field

◈ The Distribution of Charge on a Conductor

✸ The Distribution of Charge for Isolated



⅄ Isolated conductor: the smaller curvature, the bigger density σ, the stronger field, conversely.

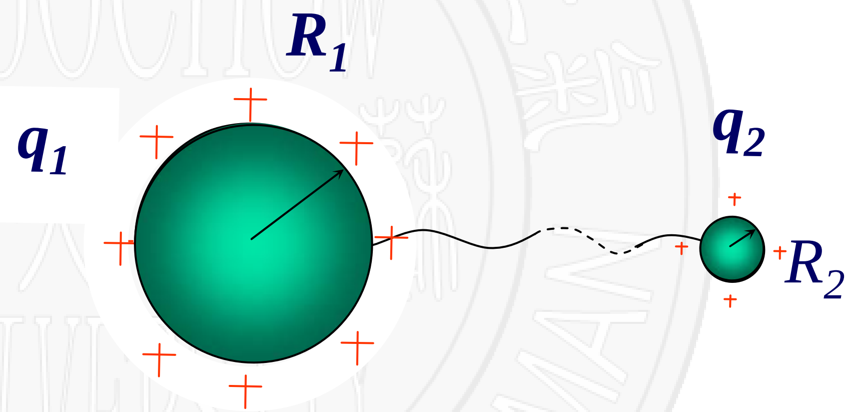
- Lightning Stroke
- Glow Discharge

Show discharging needle

2.1 Conductor in Electrostatic Field

◈ The Distribution of Charge on a Conductor

Example 2.1 A conducting sphere, R_1, Q, connected with R_2 by a very long fine wire. (a) charges q_1&q_2; (b) density σ_1, σ_2.



Solution:

When connected,
transient currents,
Until same potential

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{R_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{R_2}$$

2.1 Conductor in Electrostatic Field

$$\begin{cases} \dfrac{q_1}{q_2} = \dfrac{R_1}{R_2} \\ q_1 + q_2 = Q \end{cases} \Rightarrow \begin{cases} q_1 = \dfrac{R_1}{R_1 + R_2} Q \\ q_2 = \dfrac{R_2}{R_1 + R_2} Q \end{cases}$$

$$\sigma_1 = \frac{q_1}{4\pi R_1^2}$$

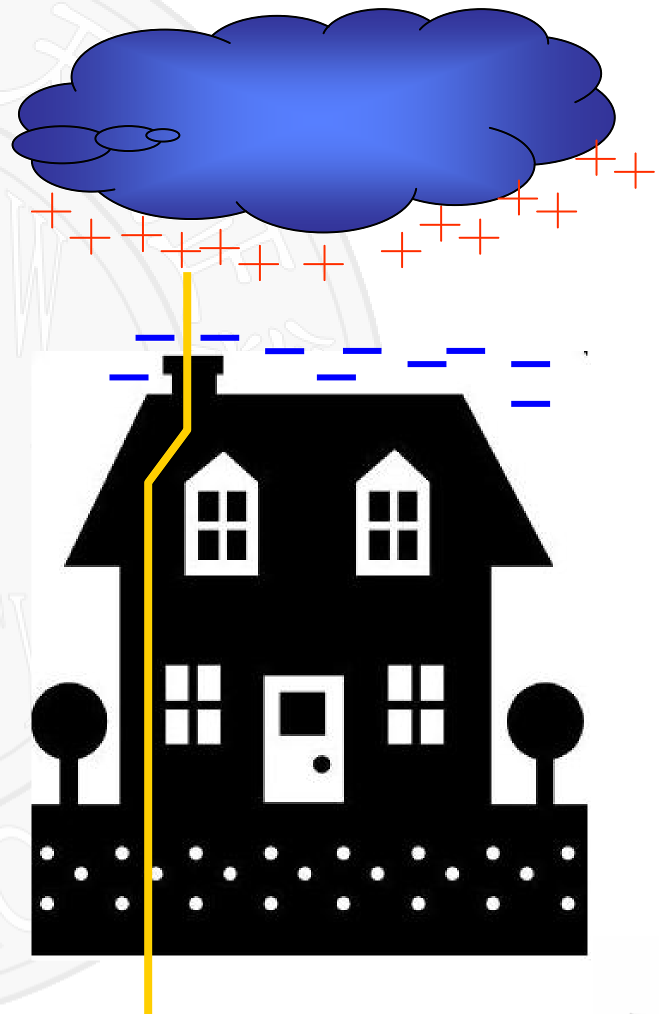
$$\sigma_2 = \frac{q_2}{4\pi R_2^2}$$

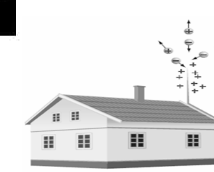
$$\frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

The larger sphere has the larger total charge but the smaller charge density

2.1 Conductor in Electrostatic Field

Show lightning stroke





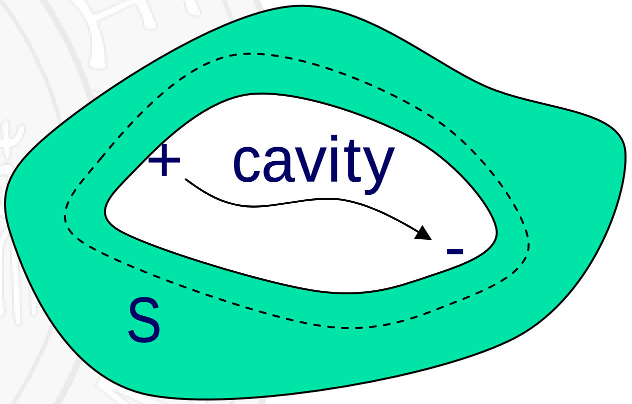
2.1 Conductor in Electrostatic Field

Hollow Conductor

- No charge in the cavity, v=const; E=0; $\rho=0;\sigma=0$.

Why?

- Equilibrium state, E=0 inside conductor.



- Gauss's law on S, $\sum q=0$, no net charge on the inner surface

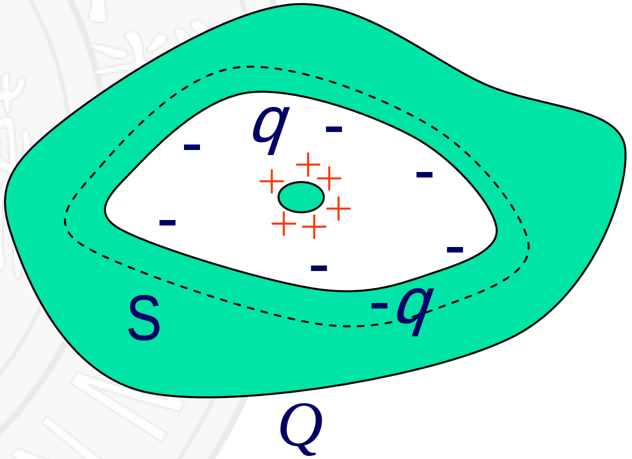
- Two equal but opposite charges on the inner surface? No, not equipotential.

2.1 Conductor in Electrostatic Field

Hollow Conductor

Charge q in a cavity, –q appears on the inner surface. Other charges reside on the outer surface.

Why?



Equilibrium state, E=0 inside conductor.

- Gauss's law on S, got $\sum q=0$.

2.1 Conductor in Electrostatic Field

◈ Hollow Conductor

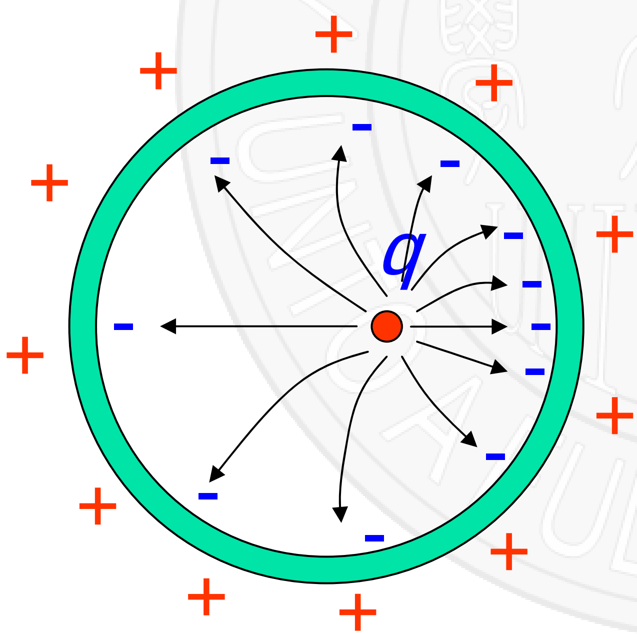
Show electric shielding

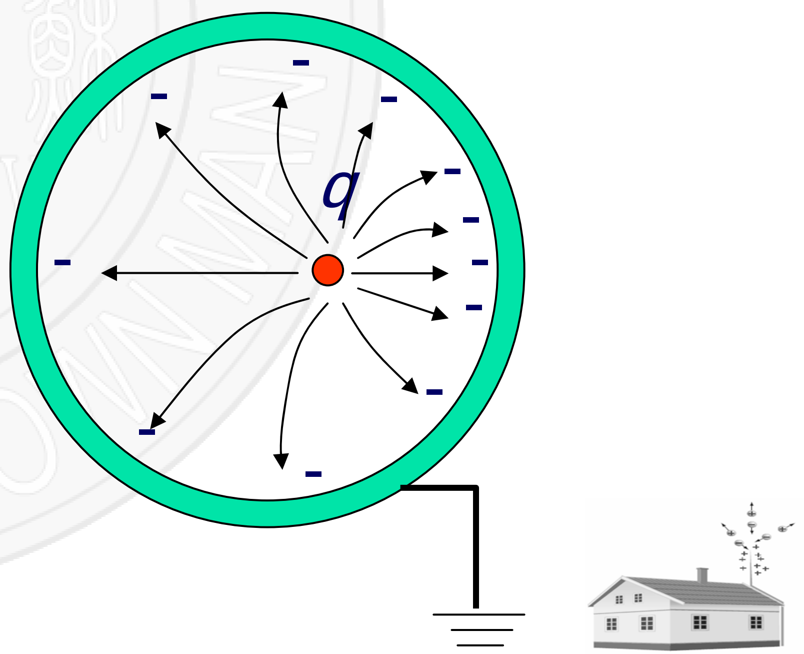
Show electric shielding

Show electric shielding

From Walter Lewin's Lecture

✷ Electric Shielding

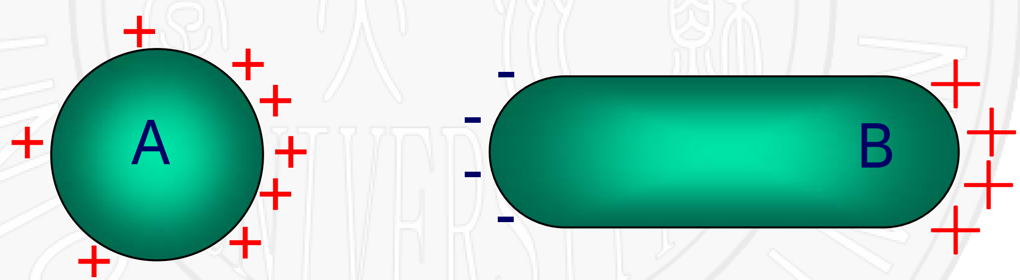




2.1 Conductor in Electrostatic Field

- Applications for Electric Lines & Equilibrium

  - When a positively charged conductor A approaches a neutral isolated conductor B, Show that (a) B's potential is increased; (b) the induced charges on nearer side never be bigger than the charges on A.



  - Show that an isolated uncharged conductor has the same potential with earth.

2.1 Conductor in Electrostatic Field

- Applications for Electric Lines & Equilibrium

  - A large, insulated, hollow conductor carries a charge $+q$. A small metal ball carrying a charge $-q$ is lowered by a thread through a small opening in the top of the conductor, allowed to touch the inner surface, and then withdrawn. What is then the charge on (a) the conductor and (b) the ball?