Objective

- So far, we have considered point charges. But how can we treat more complicated distributions, e.g., the field of a charged wire, a charged sphere or a charged ring?
- Two methods
- Method #1: Divide the distribution into infinitesimal elements dE and ***integrate*** to get the full electric field.
- Method #2: If there is some special symmetry of the distribution, use Gauss' Law to derive the field.

Gauss' Law

The flux of electric field through a closed surface is proportional to the charge enclosed by the surface.

Conductors and Insulators

Conductors and Insulators

A conductor contains charges that are free to move (electrons are weakly bound to atoms)

Example: metals

An insulator contains charges that are NOT free to move (electrons are strongly bound to atoms)

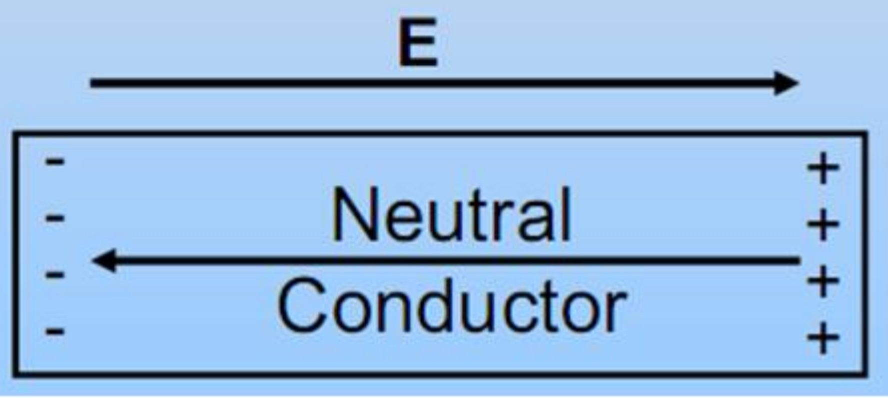
Examples: plastic, paper, wood

Conductors

Conductors have free charges

→ E must be zero inside the conductor

→ Conductors are equipotential objects

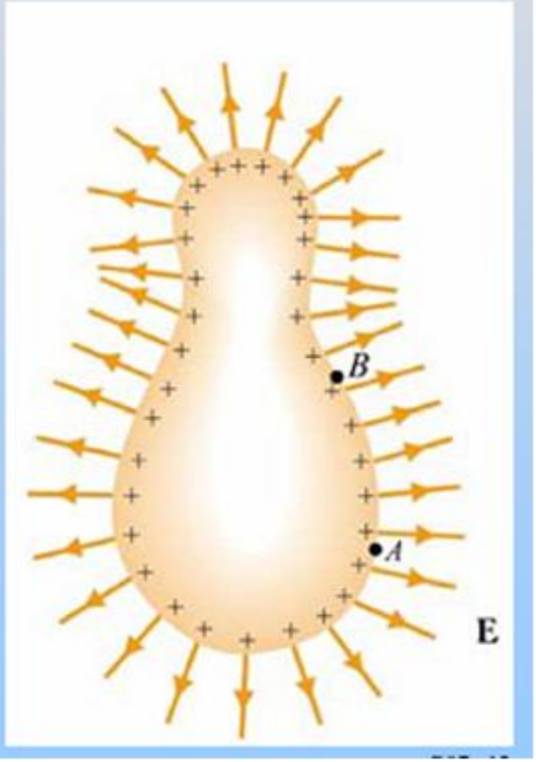


Conductors in Equilibrium

Conductors are equipotential objects:

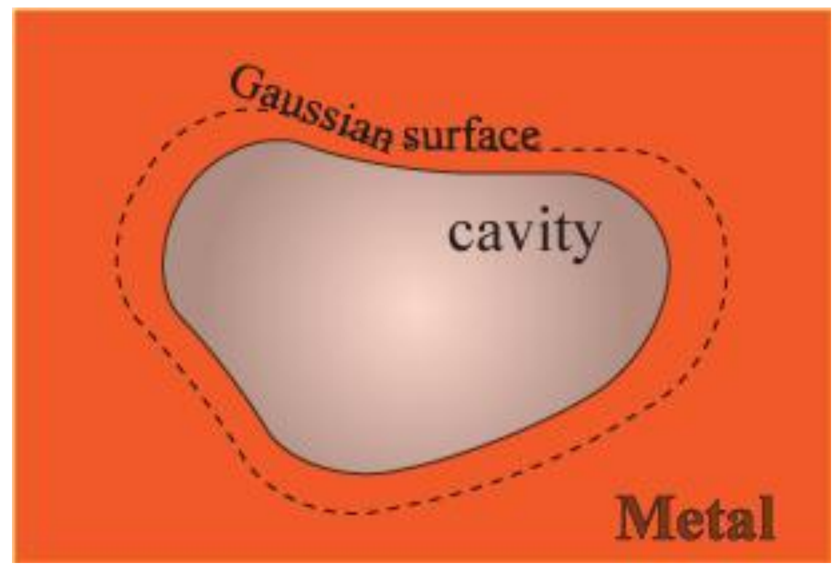
1) E = 0 inside
2) Net charge inside is 0
3) E perpendicular to surface
4) Excess charge on surface

$$E = \sigma / \varepsilon_0$$



Cavities in Conductors

- a) Isolated Copper block with net charge. The electric field inside is 0.
- b) Charged copper block with cavity. Put a Gaussian surface around the cavity. The E field inside a conductor is 0. That means that there is no flux through the surface and consequently, the surface does not enclose a net charge. There is no net charge on the walls of the cavity

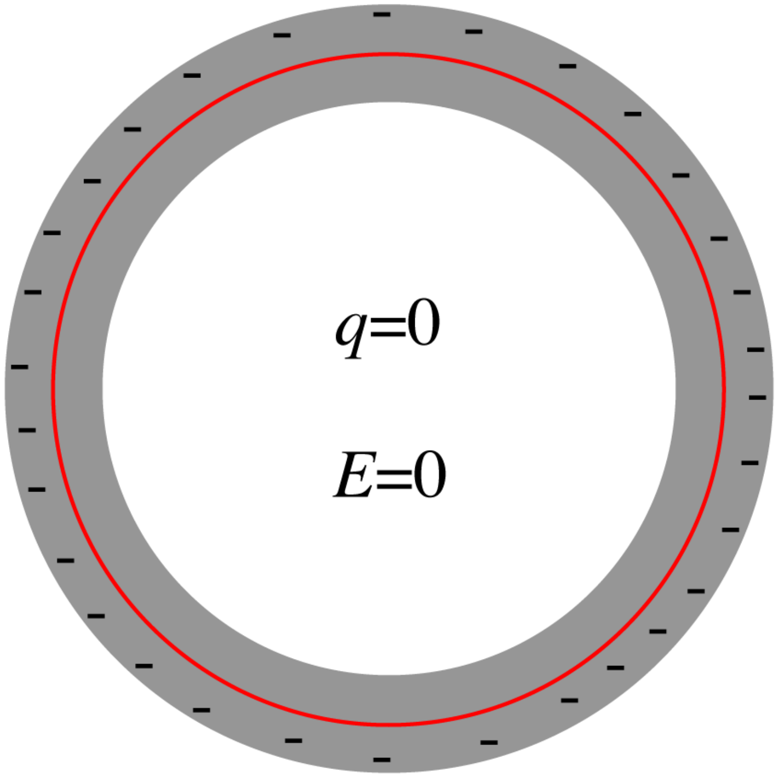


Shielding

- An interesting application of Gauss' Law:
- **The electric field inside a charged conductor is zero.**
- Think about it physically…
  - The conduction electrons will move in response to any electric field.
  - Thus the excess charge will move to the surface of the conductor.
  - So for any Gaussian surface inside the conductor -- encloses no charge! – the flux is 0. This implies that the electric field is zero inside the conductor.

Shielding Illustration

- Start with a hollow conductor.
- Add charge to the conducto
- The charge will move to the ***outer*** surface
- We can define a Gaussian surface that encloses zero charge
  - Flux is 0
  - Ergo - No electric field!

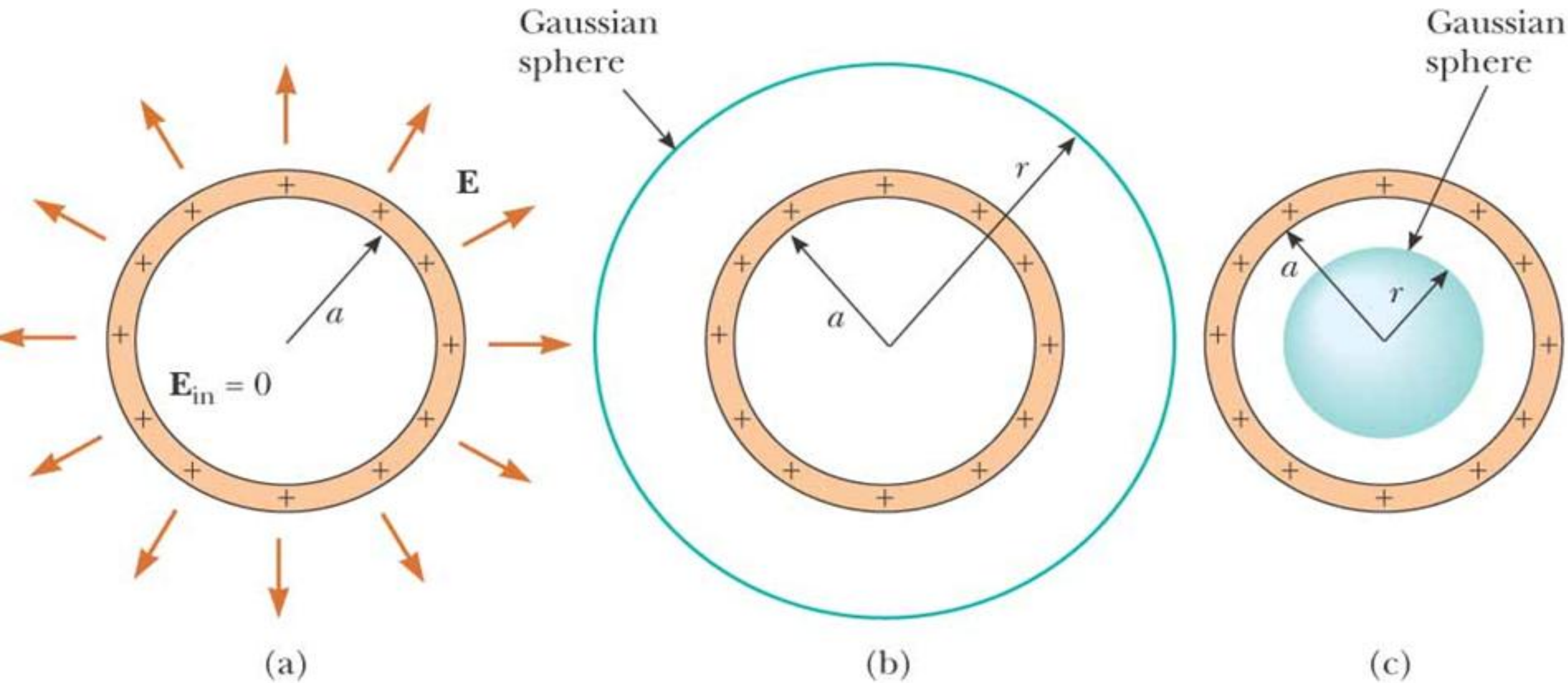


Lightning Strikes a Car

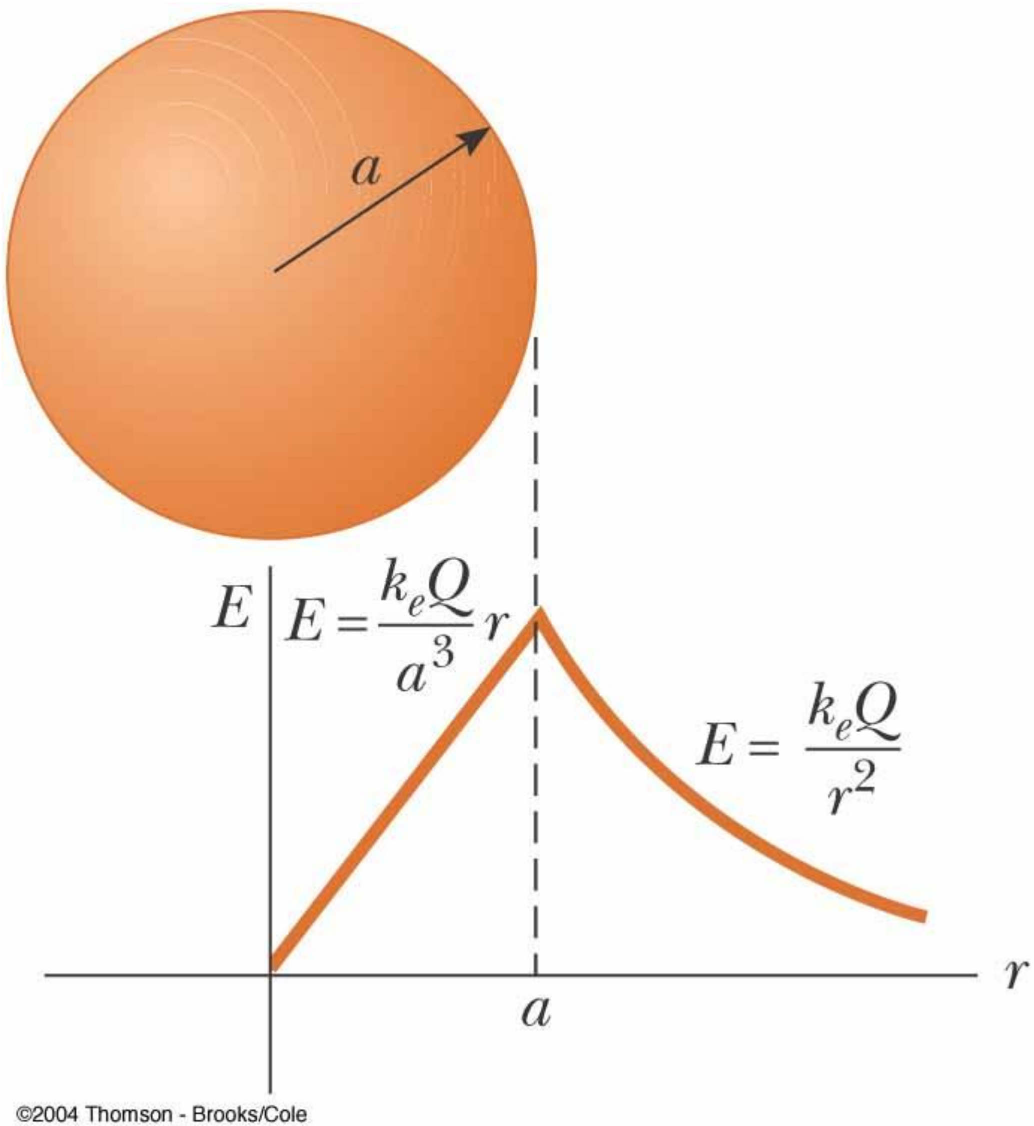
High Voltage Laboratory,
Technical University Berlin, Germany

The crash-test dummy is safe, but the right front tire didn't make it …

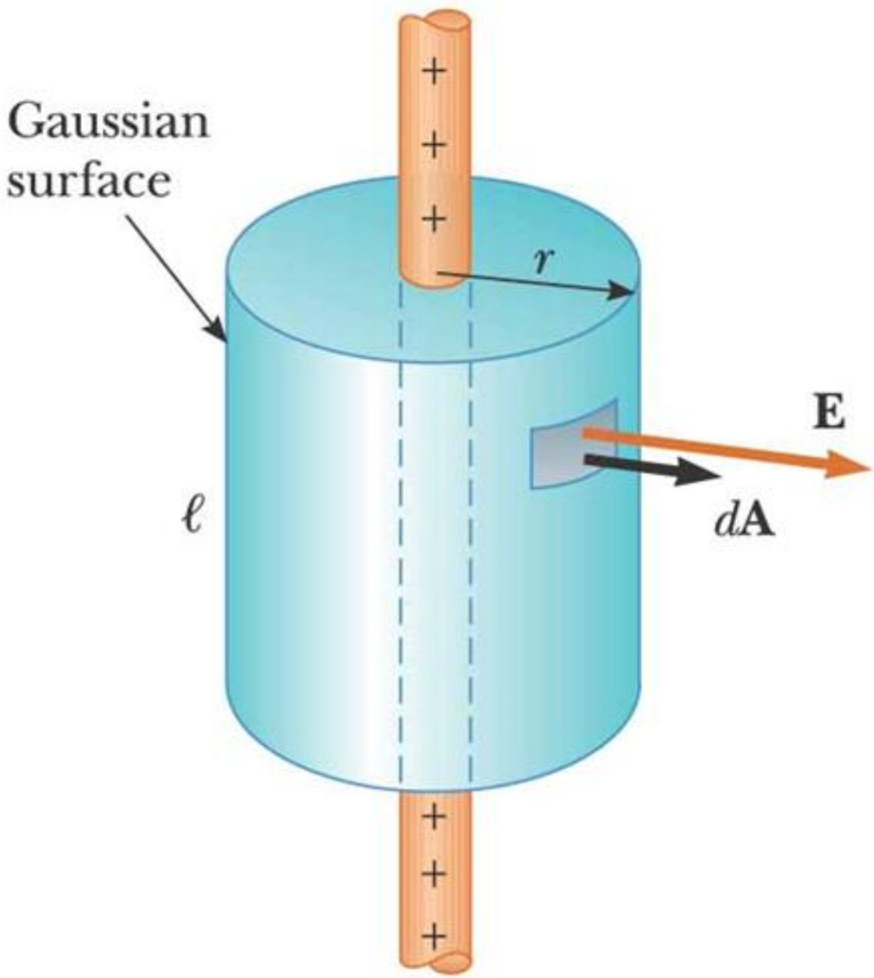
Applications of Gauss' law



A uniformly charged sphere



Applications of Gauss' law



(a)

$$\phi_E = 2\pi r l E = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r \varepsilon_0}$$

Electric Field of a Nonconducting Plane Sheet of Charge

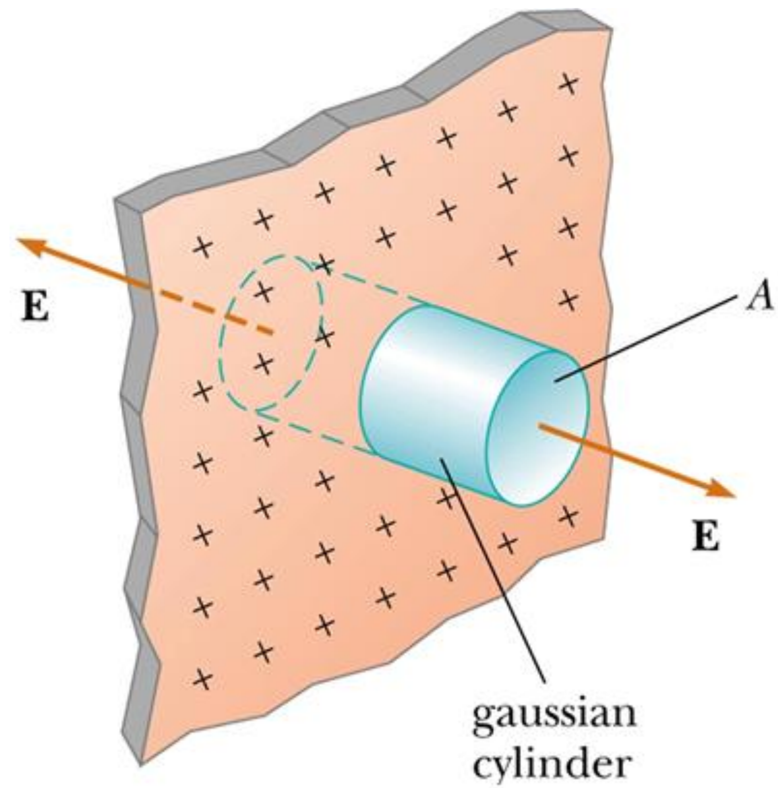
Charge by unit area

$\Phi_E = E(2A) = Q/\varepsilon_0 = \sigma A/\varepsilon_0$

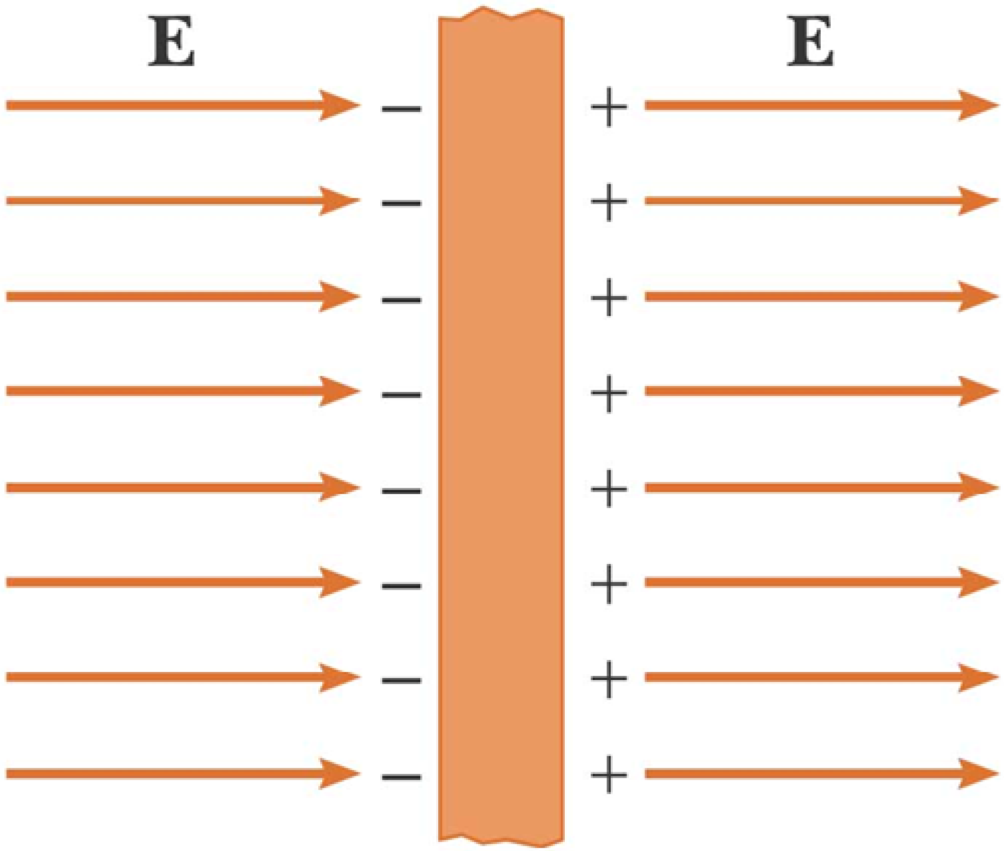
- Use a cylindrical Gaussian surface
- The flux through the ends is *EA*, there is no field through the curved part of the surface
- The electric field is:

$$E = \frac{\sigma}{2\varepsilon_o}$$

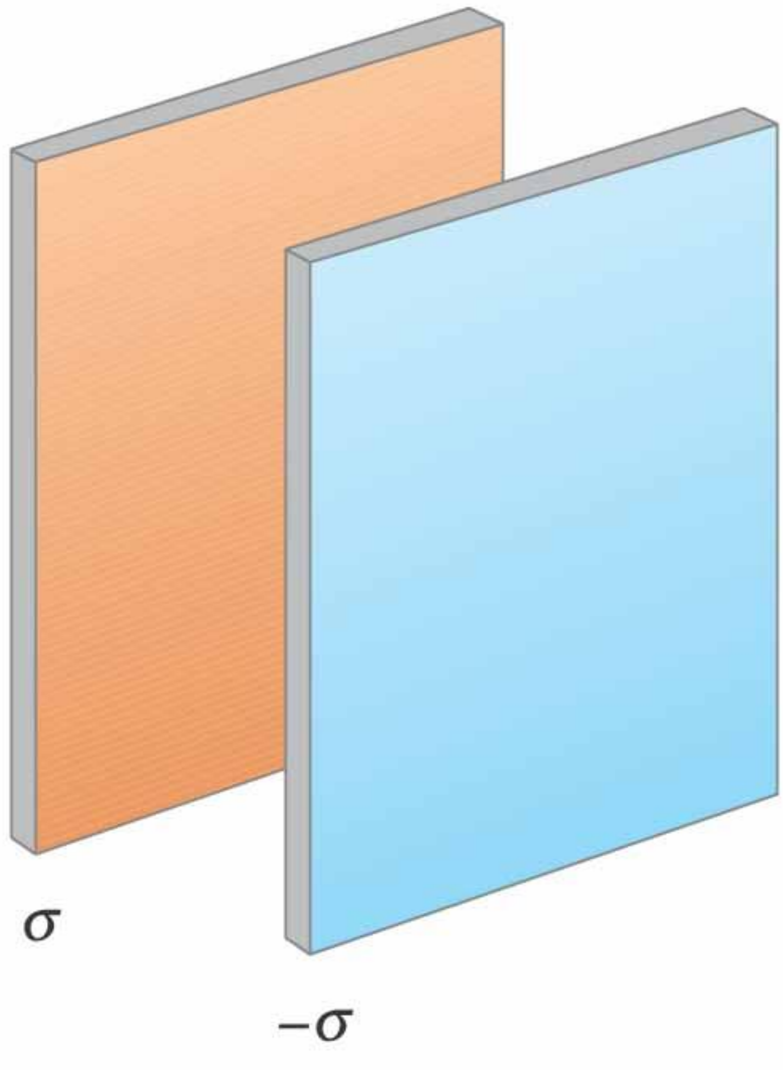
- Note, the field is uniform



Applications of Gauss' law



Applications of Gauss' law



Applications of Gauss' law