

Flux Capacitor (Operational)

Physics 2102

Lecture 4

Gauss' Law II

Version: 1/23/07



Carl Friedrich Gauss
1777-1855

HW and Exam Solutions

- www.phys.lsu.edu/classes/spring2007/phys2102/Solutions/index.html
- USERNAME: Phys2102
- Password: Solution1
- Both are: cAsE SenSiTivE!

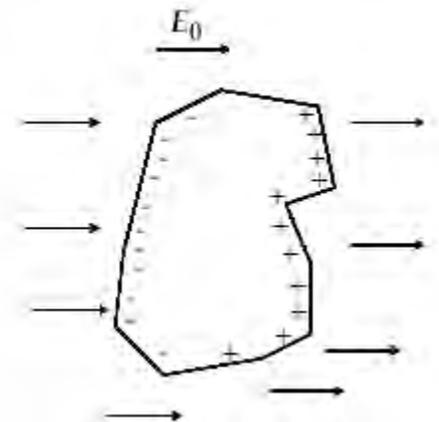
Properties of conductors

Inside a conductor in electrostatic **equilibrium**, the electric field is **ZERO**. Why?

Because if the field is not zero, then charges inside the conductor would be moving.

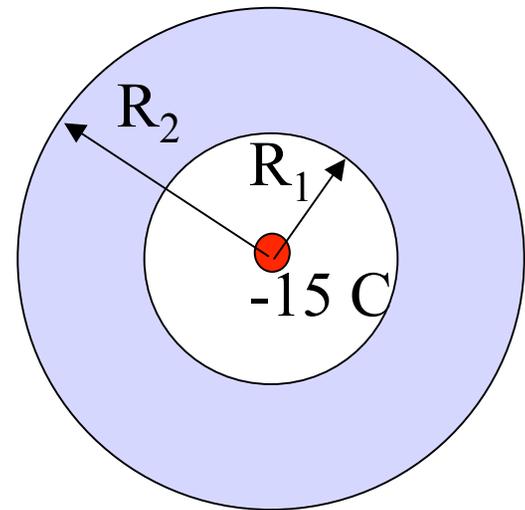
SO: charges in a conductor redistribute themselves wherever they are needed to make the field inside the conductor ZERO.

Excess charges are always on the **surface** of the conductors.



Gauss' Law: Example

- A spherical conducting shell has an excess charge of $+10\text{ C}$.
- A point charge of -15 C is located at center of the sphere.
- Use Gauss' Law to calculate the charge on inner and outer surface of sphere

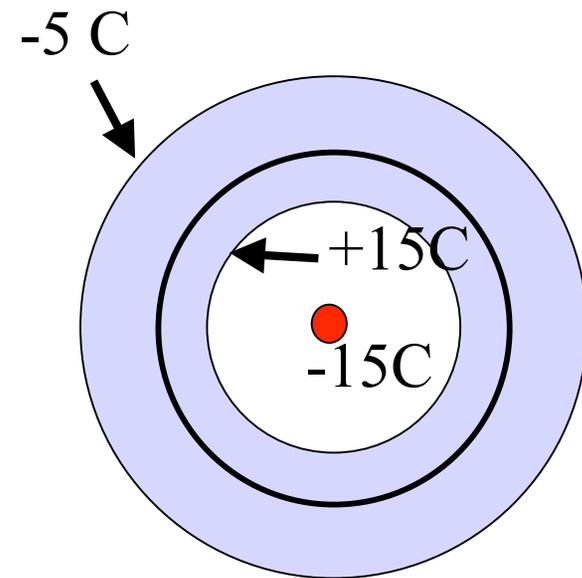


- (a) Inner: $+15\text{ C}$; outer: 0
- (b) Inner: 0 ; outer: $+10\text{ C}$
- (c) Inner: $+15\text{ C}$; outer: -5 C



Gauss' Law: Example

- Inside a conductor, $E = 0$ under static equilibrium! Otherwise electrons would keep moving!
- Construct a Gaussian surface inside the metal as shown. (Does not have to be spherical!)
- Since $E = 0$ inside the metal, flux through this surface = 0
- Gauss' Law says total charge enclosed = 0
- Charge on inner surface = +15 C



Since TOTAL charge on shell is +10 C,
Charge on outer surface = +10 C - 15 C = -5 C!

Faraday's Cage

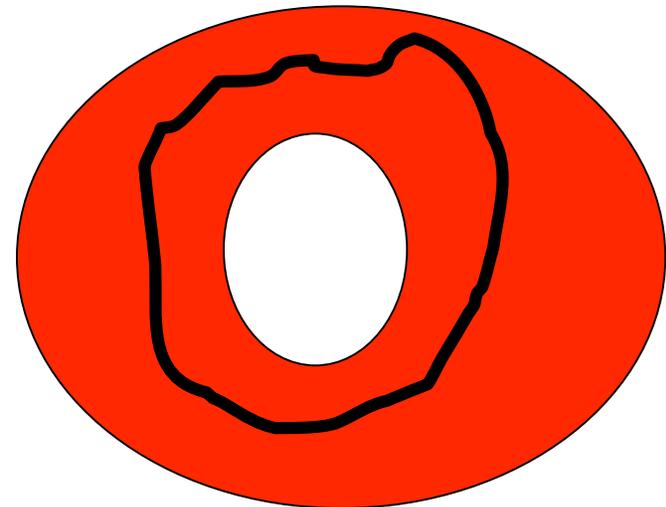
- Given a hollow conductor of arbitrary shape. Suppose an excess charge Q is placed on this conductor. Suppose the conductor is placed in an external electric field. How does the charge distribute itself on outer and inner surfaces?

(a) Inner: $Q/2$; outer: $Q/2$

(b) Inner: 0; outer: Q 

(c) Inner: Q ; outer: 0

- Choose any arbitrary surface inside the metal
- Since $E = 0$, flux = 0
- Hence total charge enclosed = 0
- All charge goes on outer surface!



Inside cavity is “shielded” from all external electric fields! “Faraday Cage effect”

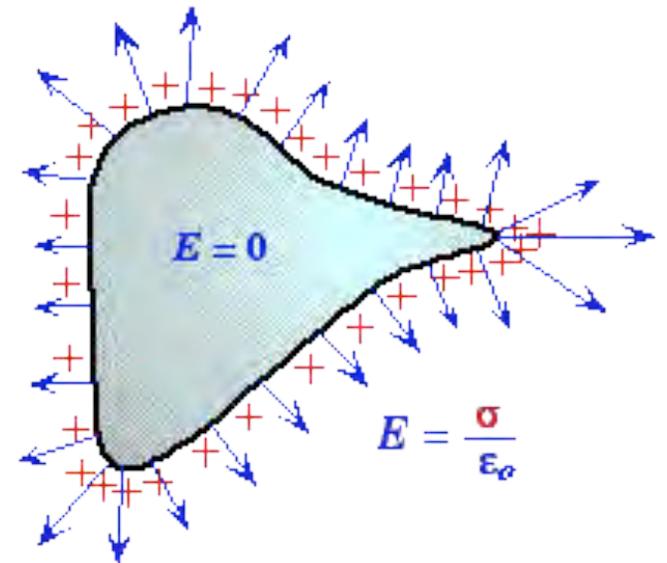
More Properties of conductors

We know the field inside the conductor is zero, and the excess charges are all on the surface. The charges produce an electric field outside the conductor.

On the **surface of conductors** in electrostatic equilibrium, the **electric field** is always **perpendicular** to the surface.

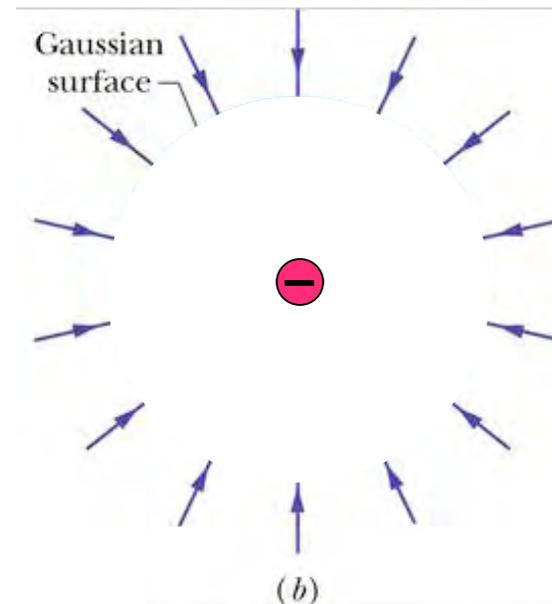
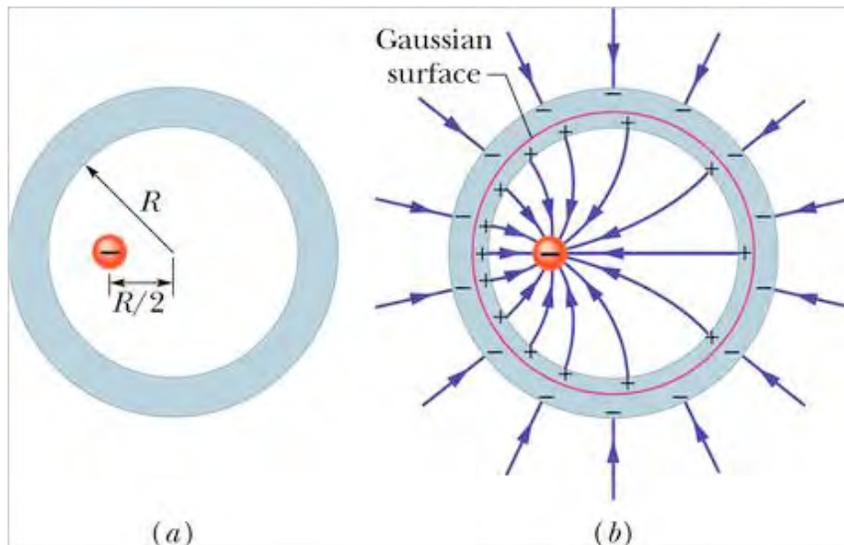
Why?

Because if not, charges on the surface of the conductors would move with the electric field.



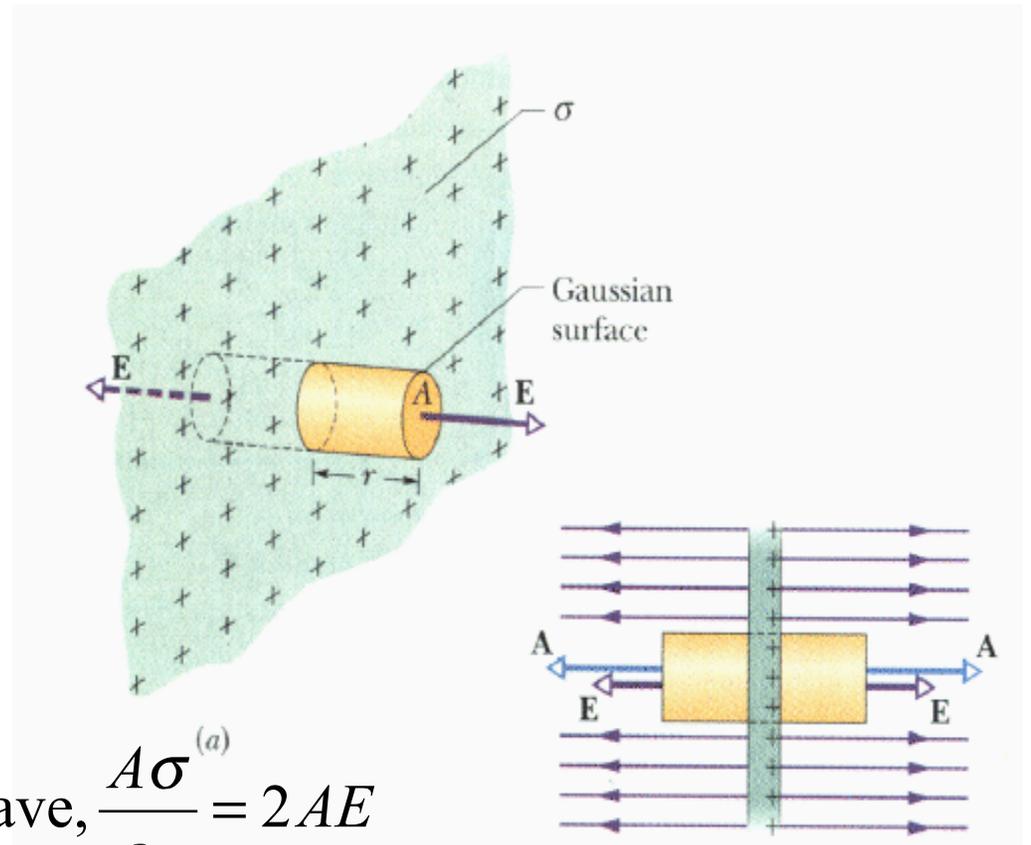
Charges in conductors

- Consider a conducting shell, and a negative charge inside the shell.
- Charges will be “induced” in the conductor to make the field inside the conductor zero.
- Outside the shell, the field is the same as the field produced by a charge at the center!



Gauss' Law: Example

- Infinite **INSULATING** plane with uniform charge density σ
- E is **NORMAL** to plane
- Construct Gaussian box as shown

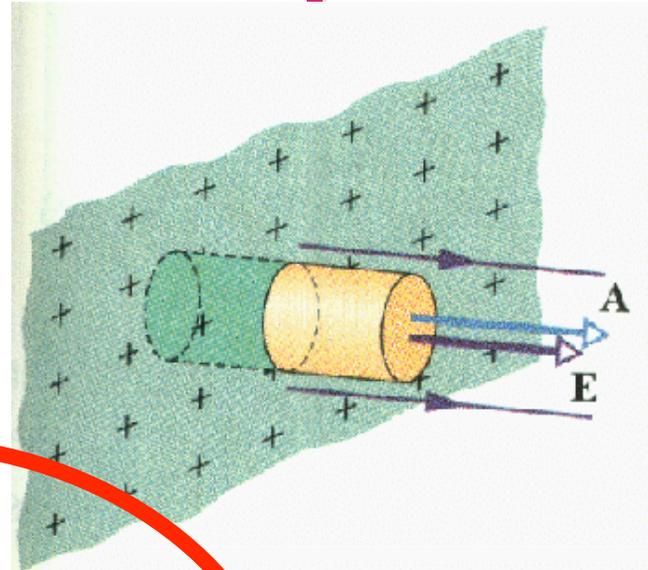


Applying Gauss' law $\frac{q}{\epsilon_0} = \Phi$, we have, $\frac{A\sigma}{\epsilon_0} = 2AE$

Solving for the electric field, we get $E = \frac{\sigma}{2\epsilon_0}$

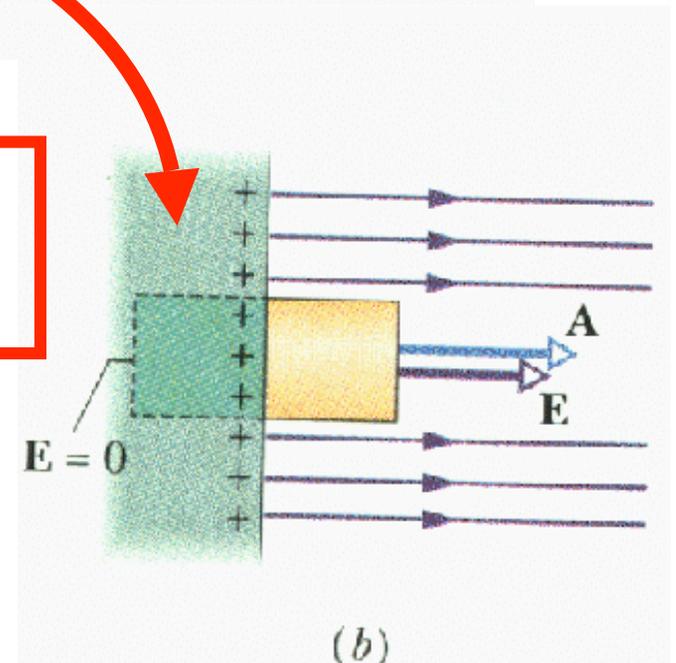
Gauss' Law: Example

- Infinite **CONDUCTING** plane with uniform areal charge density σ
- E is **NORMAL** to plane
- Construct Gaussian box as shown.
- Note that $E = 0$ inside conductor



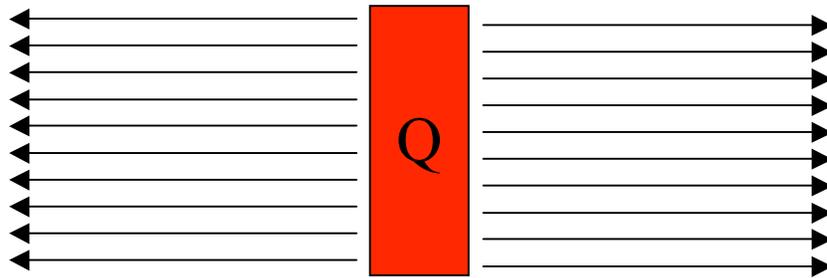
Applying Gauss' law, we have, $\frac{A\sigma}{\epsilon_0} = AE$

Solving for the electric field, we get $E = \frac{\sigma}{\epsilon_0}$



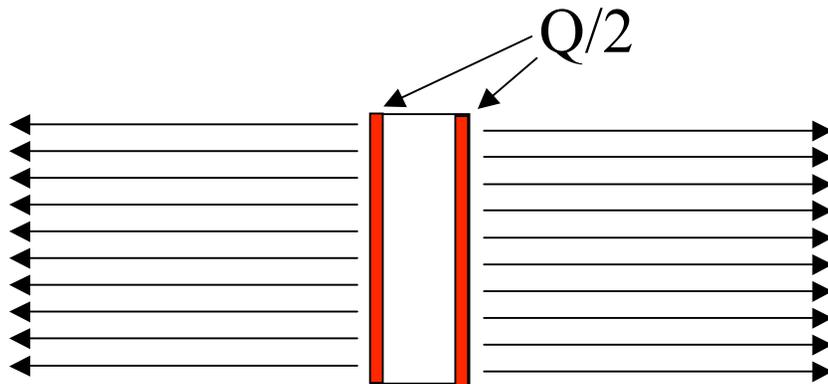
For an insulator, $E = \sigma / 2\epsilon_0$, and for a conductor, $E = \sigma / \epsilon_0$. Does the charge in an insulator produce a weaker field than in a conductor?

Insulating and conducting planes



$$E = \frac{\sigma}{2\epsilon_0} = \frac{Q}{2A\epsilon_0}$$

Insulating plate: charge distributed homogeneously.



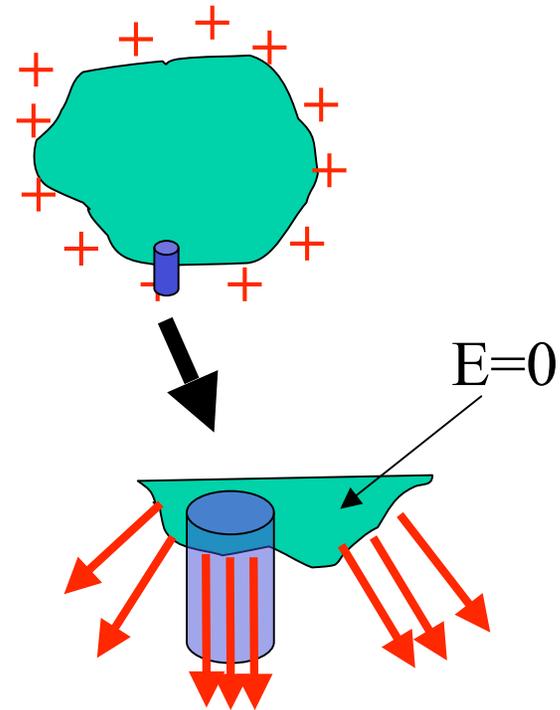
$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{2A\epsilon_0}$$

Conducting plate: charge distributed on the outer surfaces.

Gauss' Law: Example

- Charged conductor of arbitrary shape: no symmetry; non-uniform charge density
- What is the electric field near the surface where the local charge density is σ ?

- (a) σ/ϵ_0 
- (b) Zero
- (c) $\sigma/2\epsilon_0$



Applying Gauss' law, we have, $\frac{A\sigma}{\epsilon_0} = AE$

Solving for the electric field, we get $E = \frac{\sigma}{\epsilon_0}$

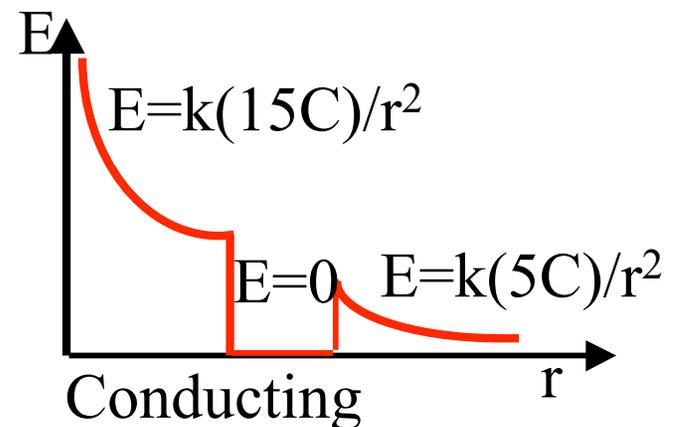
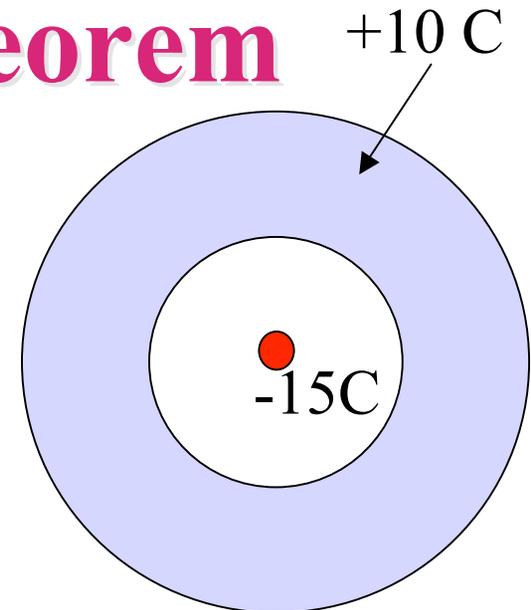
THIS IS A
GENERAL
RESULT FOR
CONDUCTORS!

Electric fields with spherical symmetry: shell theorem

A spherical shell has a charge of $+10\text{C}$ and a point charge of -15C at the center. What is the electric field produced OUTSIDE the shell?

If the shell is conducting:

And if the shell is insulating?



Charged Shells

Behave Like a Point Charge of Total Charge "Q" at the Center Once Outside the Last Shell!

Summary:

- Gauss' law provides a very direct way to compute the **electric flux**.
- In situations with **symmetry**, knowing the flux allows to compute the fields reasonably easily.
- Field of an insulating plate: $\sigma/2\epsilon_0$; of a conducting plate: σ/ϵ_0 .
- **Properties of conductors**: field inside is zero; excess charges are always on the surface; field on the surface is perpendicular and $E=\sigma/\epsilon_0$.

