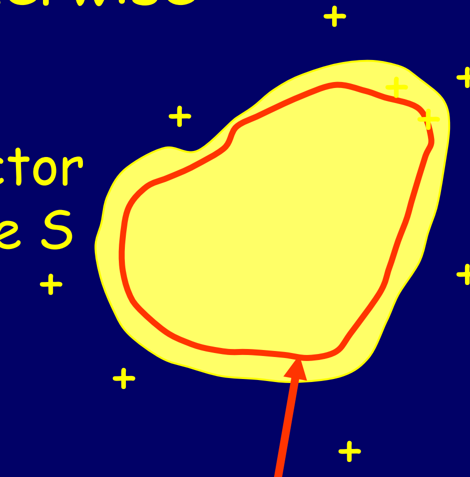
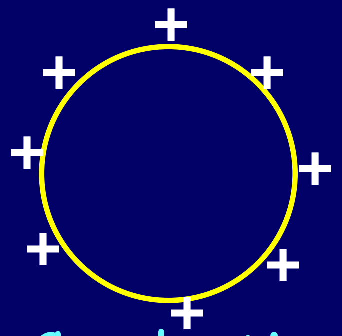
# Gauss' Law and Conductors

- We know that $E$=0 inside a conductor (otherwise the charges would move). Electrostatics!

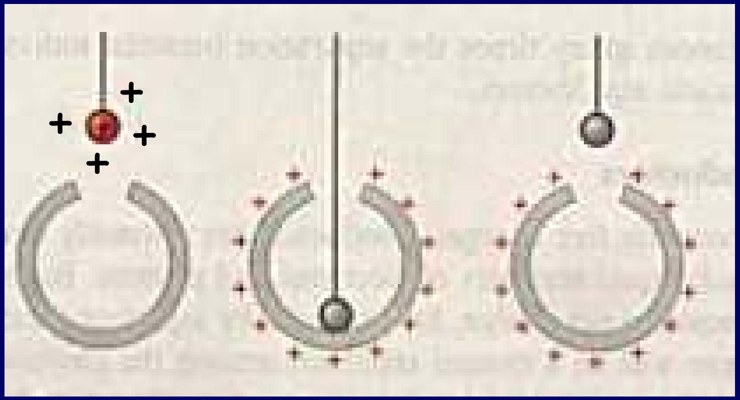



- But since $\oint \vec{E} \bullet d\vec{A} = 0 \rightarrow Q_{\text{inside}} = 0$ .

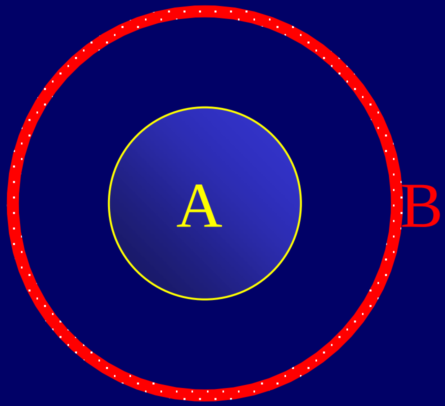
**Charges on a conductor only reside on the surface(s)!**



Conducting sphere



UL4PF4:




A blue sphere A is contained within a red spherical shell B. There is a charge $Q_A$ on the blue sphere and charge $Q_B$ on the red spherical shell.

7) The electric field in the region between the spheres is completely independent of $Q_B$ the charge on the red spherical shell.

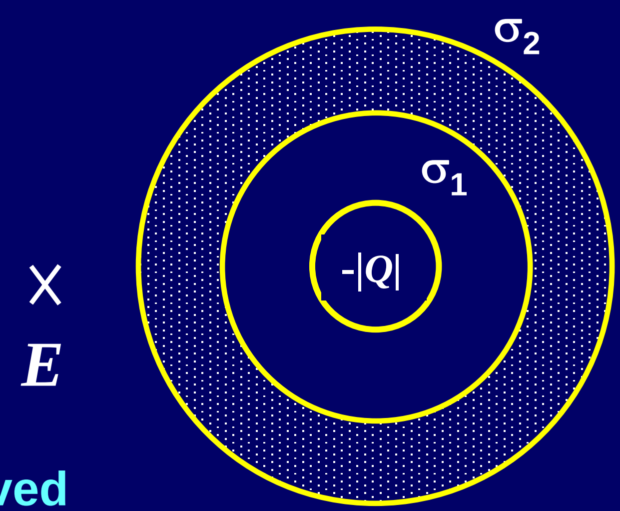
True

False

# UI4ACT1

**Consider the following two topologies:**

**A)** **A solid non-conducting sphere carries a total charge $Q$ = -3 $\mu$C distributed evenly throughout. It is surrounded by an *uncharged* conducting spherical shell.**




**B)** **Same as (A) but conducting shell removed**

**1A**

**•Compare the electric field at point X in cases A and B:**

**(a)** $E_A < E_B$ **(b)** $E_A = E_B$ **(c)** $E_A > E_B$

**1B**

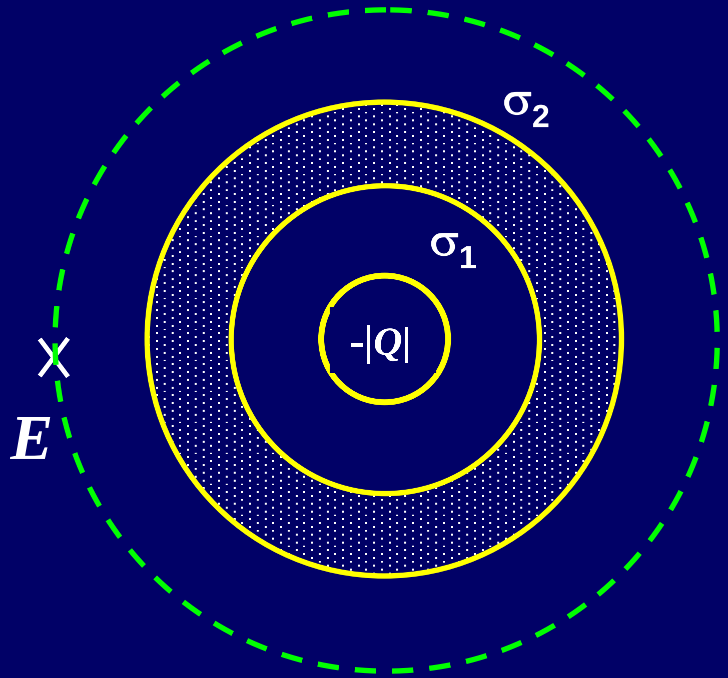
**•What is the surface charge density $\sigma_1$ on the inner surface of the conducting shell in case A?**

**(a)** $\sigma_1 < 0$ **(b)** $\sigma_1 = 0$ **(c)** $\sigma_1 > 0$

# UI4ACT1

Consider the following two topologies:

A) A solid non-conducting sphere carries a total charge $Q$ = -3 μC distributed evenly throughout. It is surrounded by an *uncharged* conducting spherical shell.




**1A**

•Compare the electric field at point X in cases A and B:

(a) $E_A < E_B$ (b) $E_A = E_B$ (c) $E_A > E_B$

- Select a sphere passing through the point X as the Gaussian surface.
- How much charge does it enclose?
  - Answer: -|$Q$|, whether or not the uncharged shell is present.

(The field at point X is determined only by the objects with NET CHARGE.)

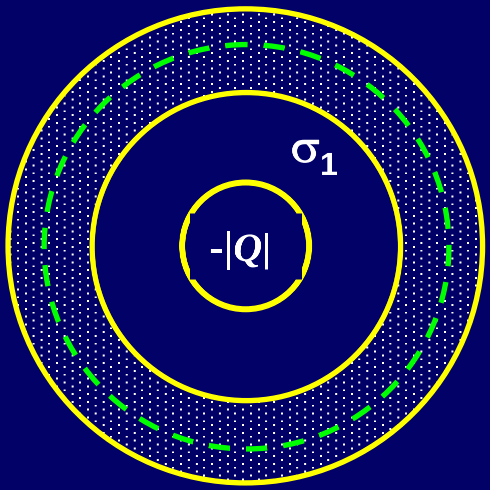
# UI4ACT1

Consider the following two topologies:

A solid non-conducting sphere carries a total charge $Q$ = -3 μC and is surrounded by an *uncharged* conducting spherical shell.

B) Same as (A) but conducting shell removed

X
$E$




**1B**

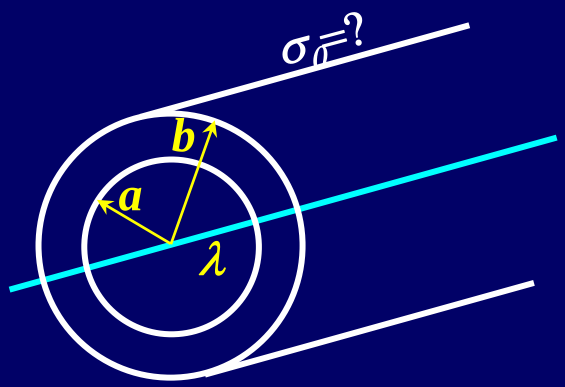
**•What is the surface charge density $\sigma_1$ on the inner surface of the conducting shell in case A?**

(a) $\sigma_1 < 0$ (b) $\sigma_1 = 0$ (c) $\sigma_1 > 0$

- Inside the conductor, we know the field $E = 0$
- Select a Gaussian surface inside the conductor
  - Since $E = 0$ on this surface, the total enclosed charge must be 0
  - Therefore, $\sigma_1$ must be positive, to cancel the charge -|$Q$|
- By the way, to calculate the actual value: $\sigma_1 = -Q / (4 \pi r_1^2)$

# Lecture 4, ACT 2

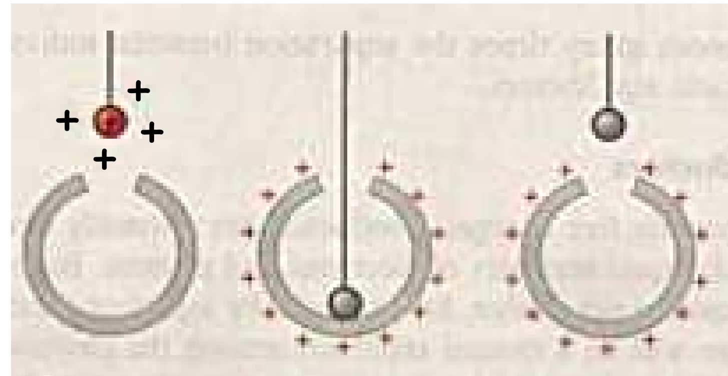
- **A line charge $\lambda$ (C/m) is placed along the axis of an uncharged conducting cylinder of inner radius $r_i = a$, and outer radius $r_o = b$ as shown.**
  - **What is the value of the charge density $\sigma_o$ (C/m$^2$) on the outer surface of the cylinder?**



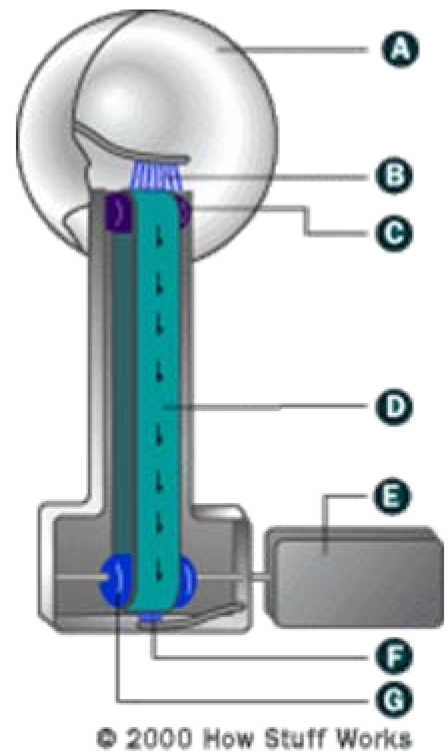

**(a)** $\sigma_o = -\frac{\lambda}{2\pi b}$ **(b)** $\sigma_O = 0$ **(c)** $\sigma_o = +\frac{\lambda}{2\pi b}$

# Testing Gauss's Law

Faraday's ice pail experiment. If Gauss's Law correct, we will never detect any charge on the inside.



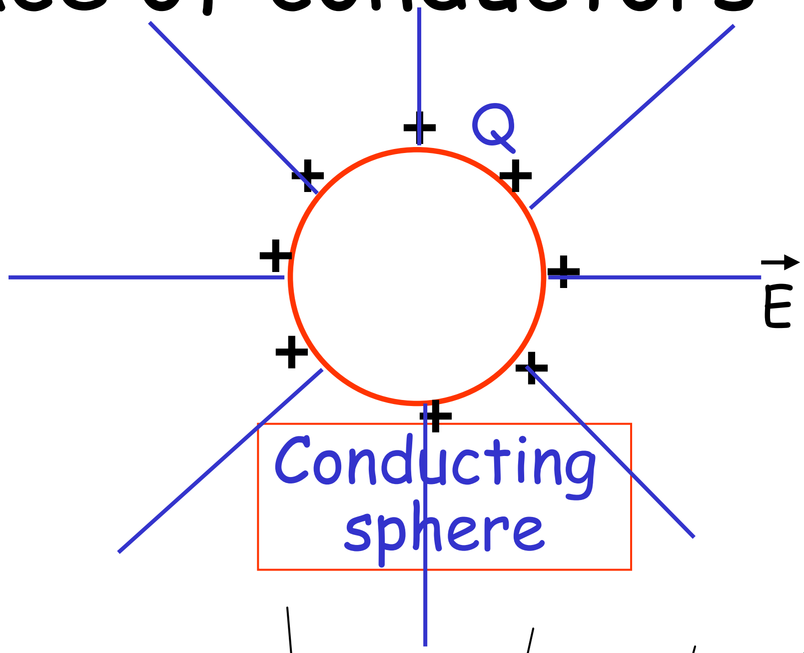
Application: Van der Graaf generator




- **A Output terminal — An aluminum or steel sphere**
- **B Upper brush — A piece of fine metal wire**
- **C Upper roller — A piece of nylon**
- **D Belt — A piece of surgical tubing**
- **E Motor**
- **F Lower brush**
- **G Lower roller — A piece of nylon covered with silicon tape**

# Fields at surface of conductors

Conducting sphere: charge distributes uniformly. $\vec{E}$ outside just like point charge Q.



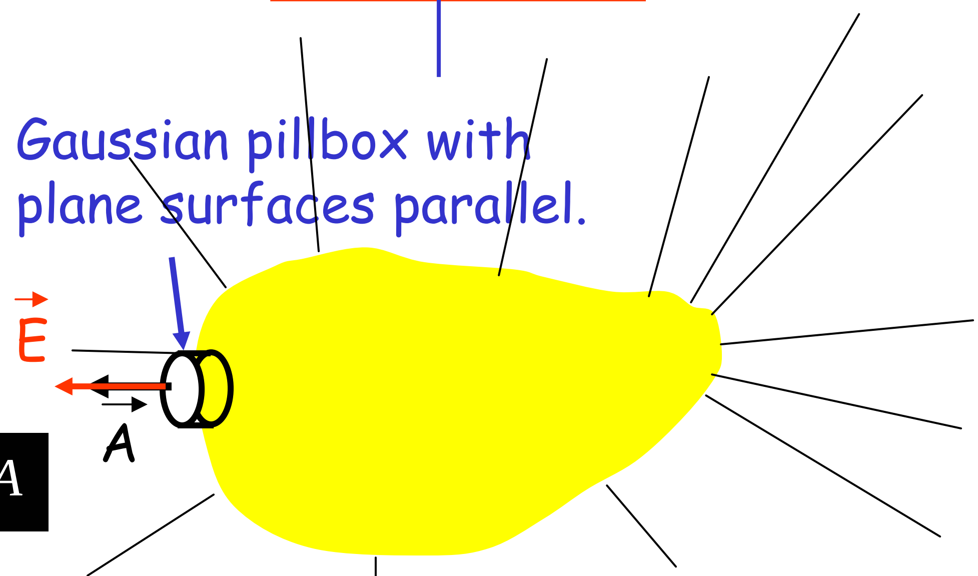

More general shape:

1. E is ⊥ to surface since there can be no component tangent.
2. Flux on cyl. surface is zero.
3. Flux on inside is zero.
4. Therefore

$$\oint \vec{E} \bullet d\vec{A} = \Phi_E = EA\cos\theta = EA$$

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

Gaussian pillbox with plane surfaces parallel.




$\vec{E}$ at surface of conductor is normal and $E = \sigma/\varepsilon_0$ .