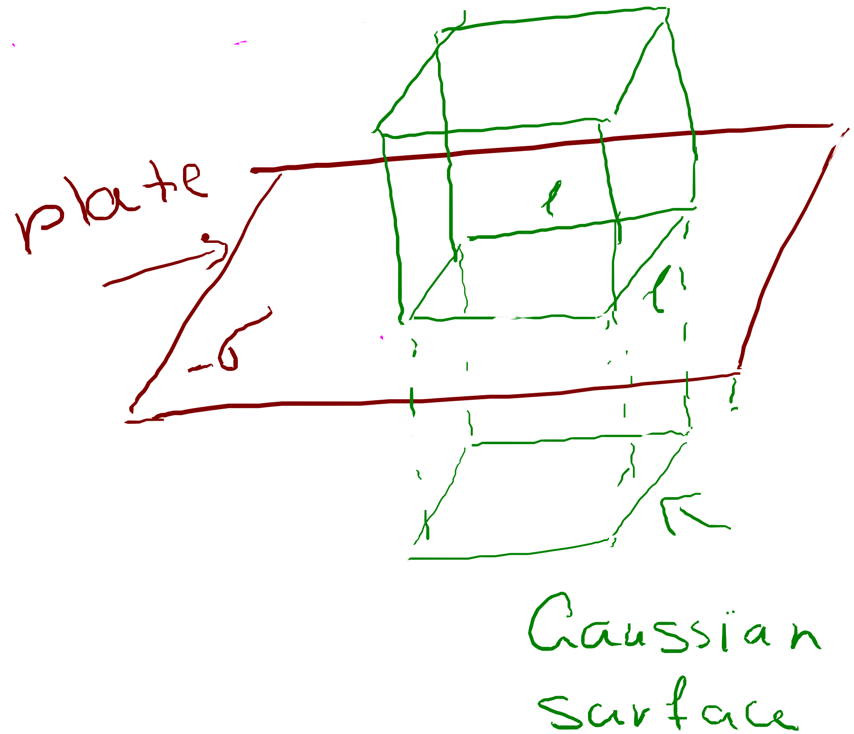
Electricity and Magnetism

- Physics 259 – L02
- Lecture 17

class activity

$$\sigma = \frac{q}{A} = \frac{q}{\ell^2}$$



$$\Phi_e = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

$$\Phi_e = \frac{q_{enc}}{\varepsilon_0} = \frac{-\sigma \ell^2}{\varepsilon_0}$$

$$\varphi = \frac{q}{\varepsilon_0}$$

$$\varphi_e = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} = \frac{\sigma \pi R^2}{\varepsilon_0}$$

Chapter 23.3-4

(please read chapter 2~~2~~3 of the textbook)

Last time

- Chapter 23.2 

This time

- Chapter 23.3 and 23.4 

23-3: A Charge~~s~~d Isolated Conductor

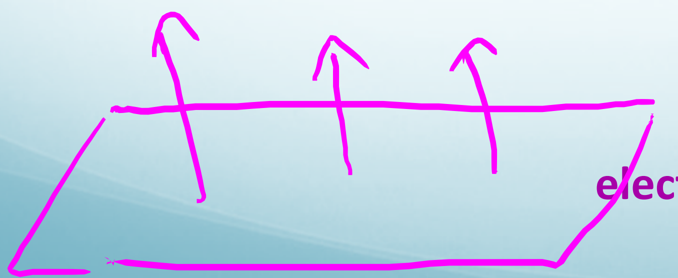
Conductors

A conductor is a material in which the charges are free to move.

This means that two things are true:

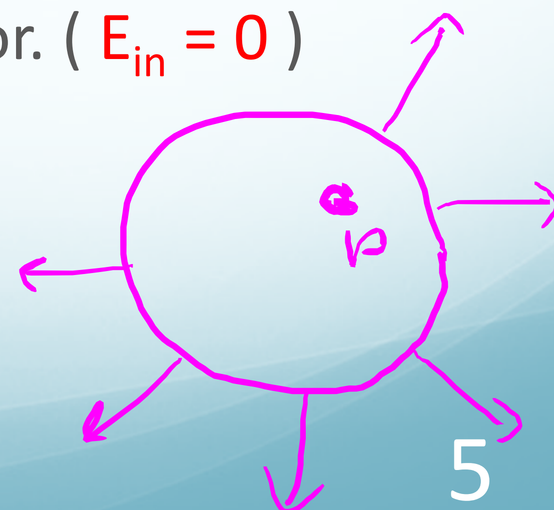
1. There is zero net charge inside a conductor. ($Q_{net} = 0$)

2. There is zero electric field inside a conductor. ($E_{in} = 0$)



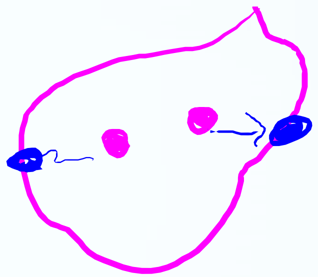
Conductor

electrostatic equilibrium



Conductors -- Explanations

1. There is zero net charge inside a conductor. ($Q_{net} = 0$)



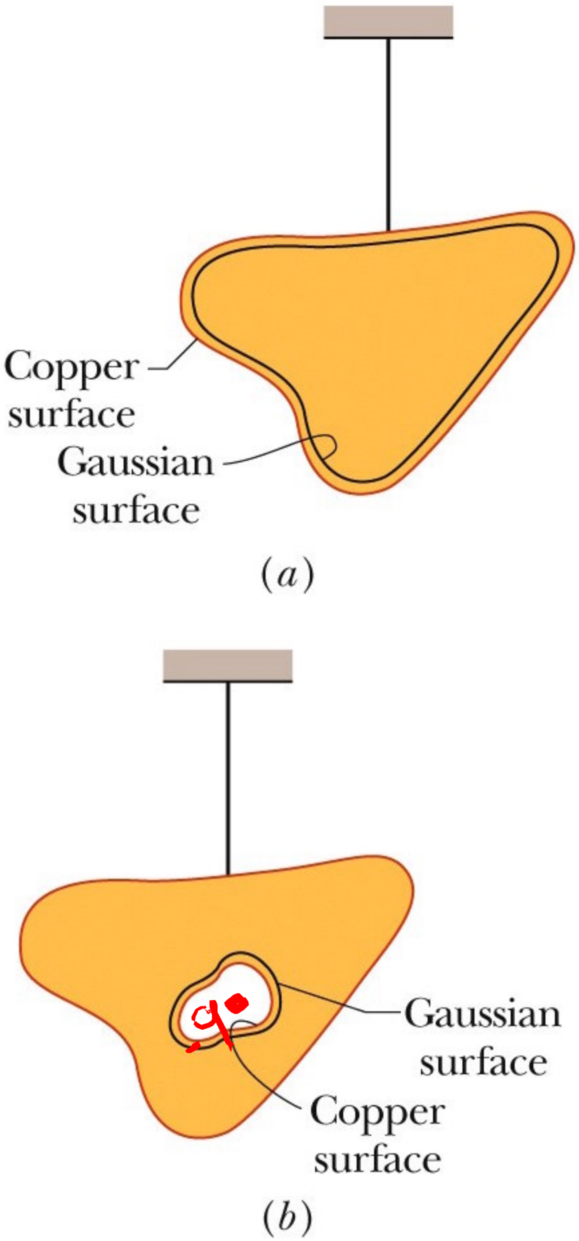
If there are 2 (or more) like charges inside a conductor then they will repel each other and push each other far away. (ie --to the surface)

2. There is zero electric field inside a conductor. ($E_{in} = 0$)

$$E = \frac{F}{q} \rightarrow F = Eq$$

If there is a non-zero E field then F = qE implies there is a net force which means charges would move until the force on them is zero – we have a STATIC situation. (Equilibrium)

Hollow Conductors



The electric field inside a conductor is zero. This immediately implies that conductors are electrically neutral in their interiors.

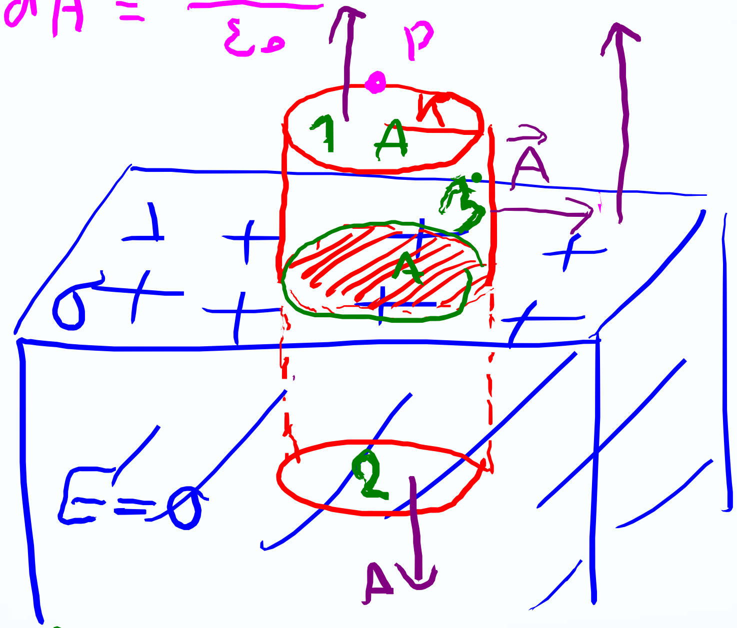
$$\oint \cancel{\vec{E}}^{\,0} \cdot d\vec{A} = 0 = \frac{q_{enc}}{\varepsilon_0} \to 0$$

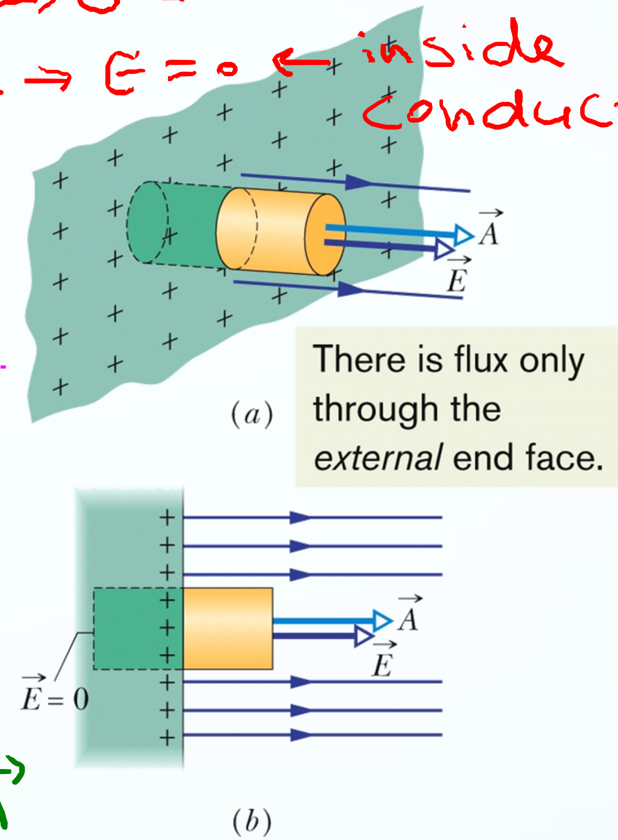
This also means that the surface of a hollow cavity inside a conductor cannot carry any excess charge. All excess charge must reside on the outside surface only.

$$\Phi_e = \oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

$1 \rightarrow \theta = 0$

$2 \rightarrow E = 0$ ← inside conductor





$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

$$\hookrightarrow \underbrace{\int_1 \vec{E}\cdot d\vec{A}}_{\theta=0} + \underbrace{\int_2 \cancel{\vec{E}}\cdot d\vec{A}}_{0} + \underbrace{\int_3 \vec{E}\cdot d\vec{A}}_{\theta=90^\circ}$$

$$\rightarrow \oint \vec{E}\cdot d\vec{A} = E\int dA = \frac{q_{enc}}{\varepsilon_0} \rightarrow E\cancel{A} = \frac{q_{enc}}{\varepsilon_0} = \frac{\sigma \cancel{A}}{\varepsilon_0}$$

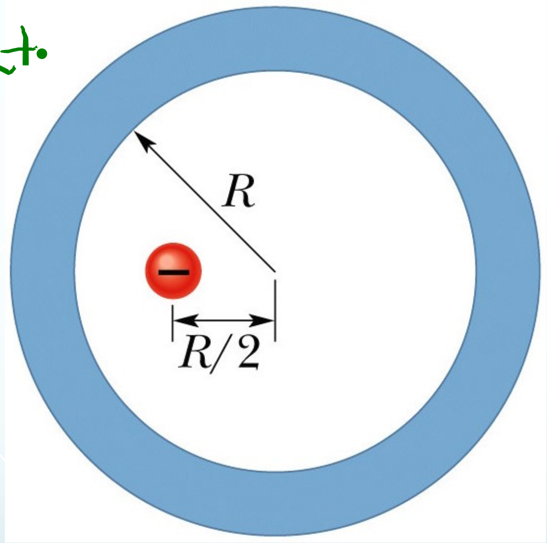
$$\rightarrow E = \frac{\sigma}{\varepsilon_0}$$

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{(conducting surface).}$$

TopHat Question

Consider a spherical metal shell of inner radius R. A point charge of -5.0 μC is located at a distance R/2 from the centre of the shell. If the shell is neutral, what is the induced charge on its **outer surface**?

85% correct.

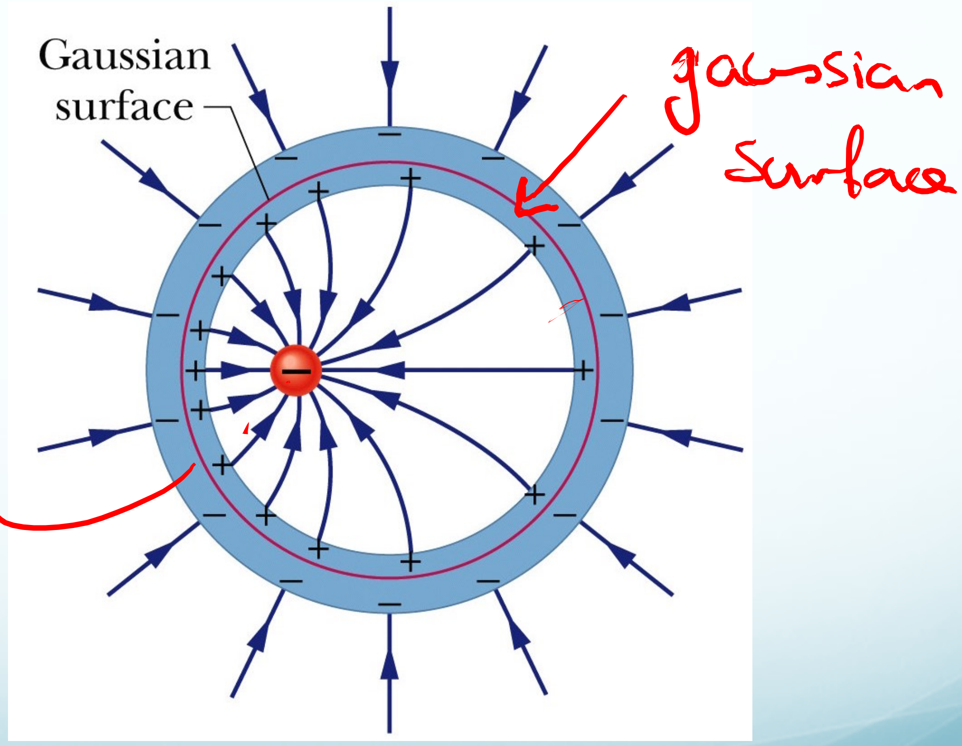


A) Zero

B) +5.0 μC

C) - 5.0 μC

- Point Charge inside is $-5 \mu C$
- Inner surface has $+5 \mu C$ non-uniformly distributed
- Outer surface has $-5 \mu C$ uniformly distributed



$E = 0$

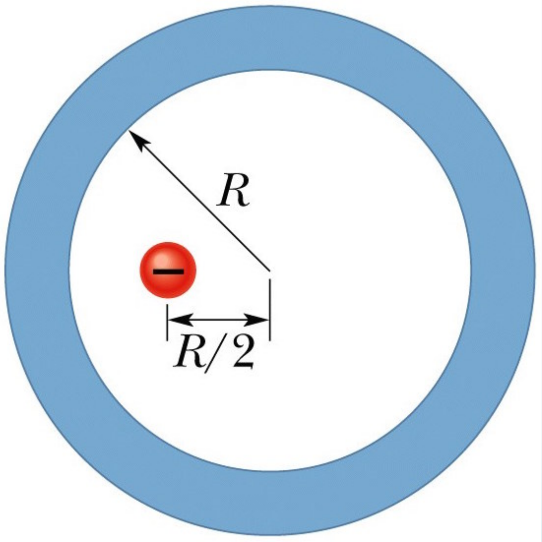
$q_{enc} = 0$

Consider a spherical metal shell of inner radius R. A point charge of - 5.0 μC is located at a distance R/2 from the centre of the shell. If the shell is neutral, are these charges uniformly distributed on the **inner surface**?

A. Yes

B. No

C. Perhaps

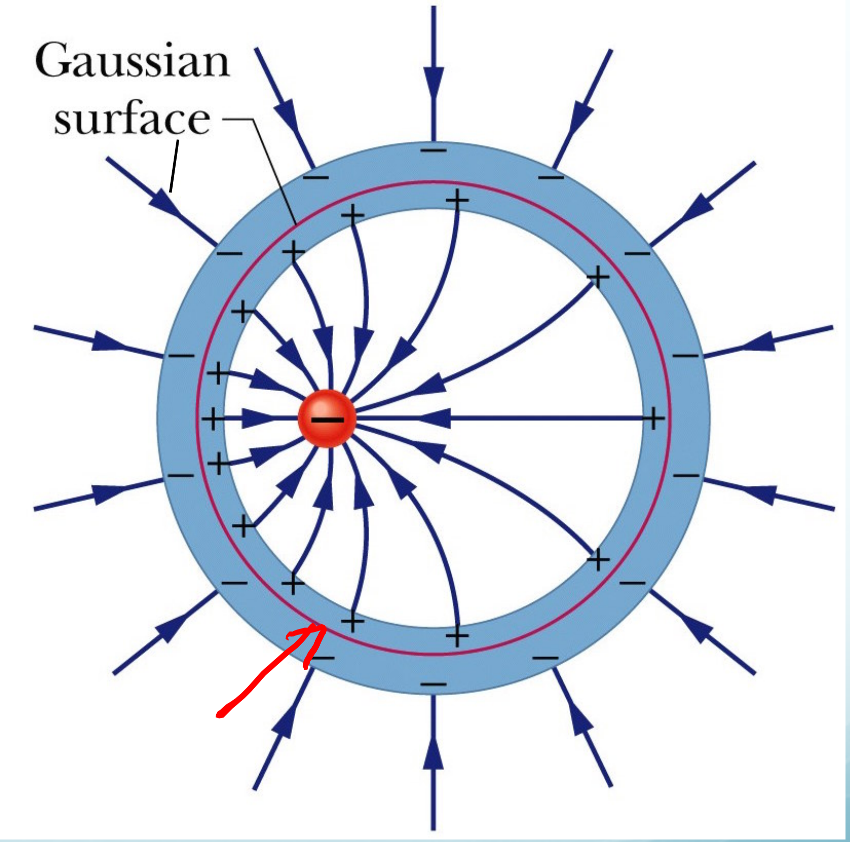


Hint: What must the electric field be inside the shell?

E = 0 inside the metal:

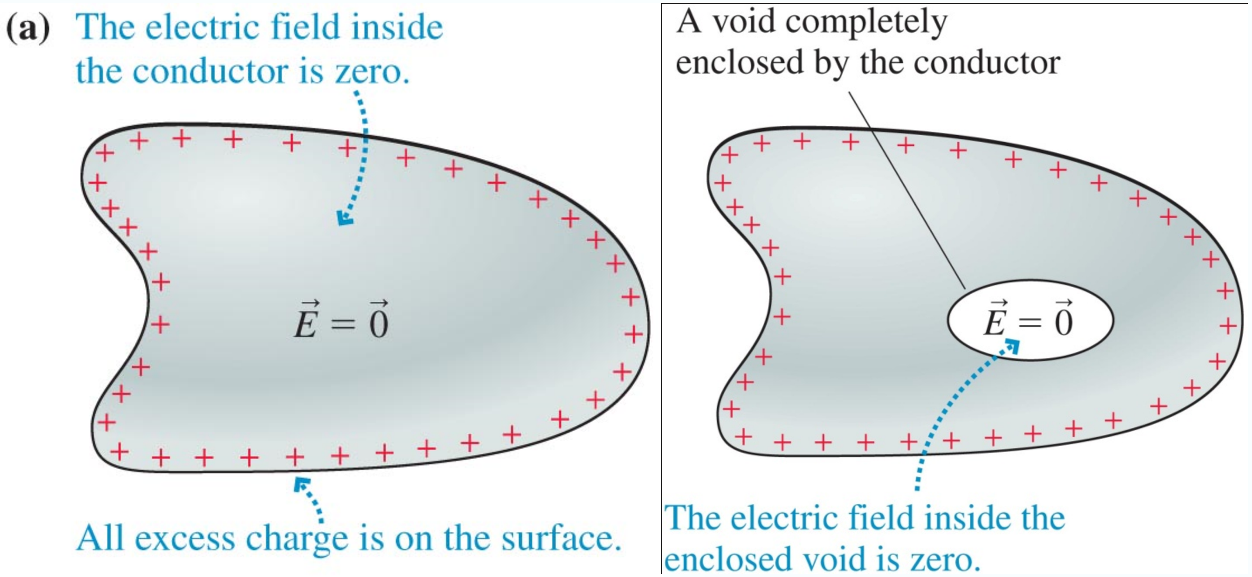
The **net charge** enclosed in the Gaussian surface must be **zero**.

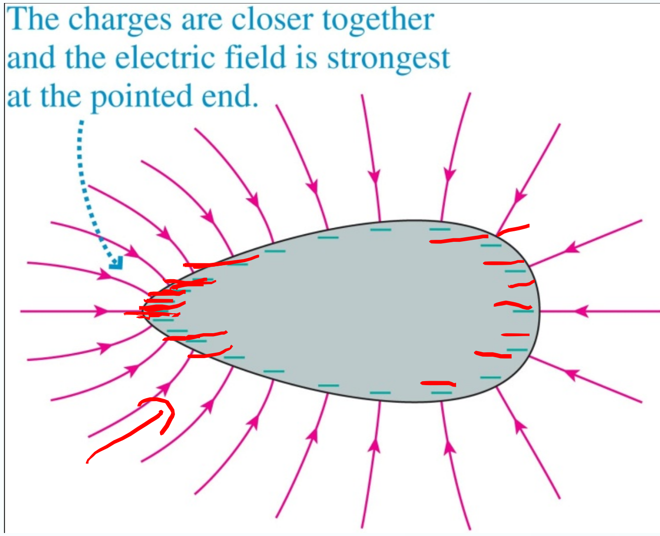
There must be +5 μC on the inside of the shell and –5 μC on the outside.

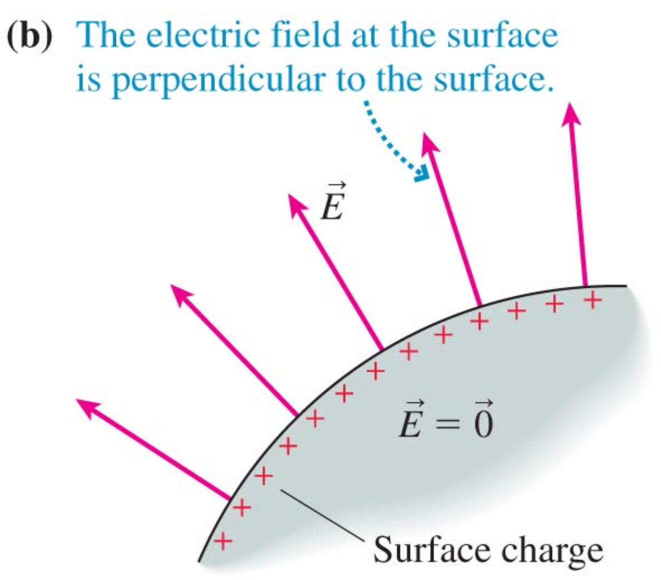


The charges on the outside "don't know about the inside since E = 0 inside the conductor.

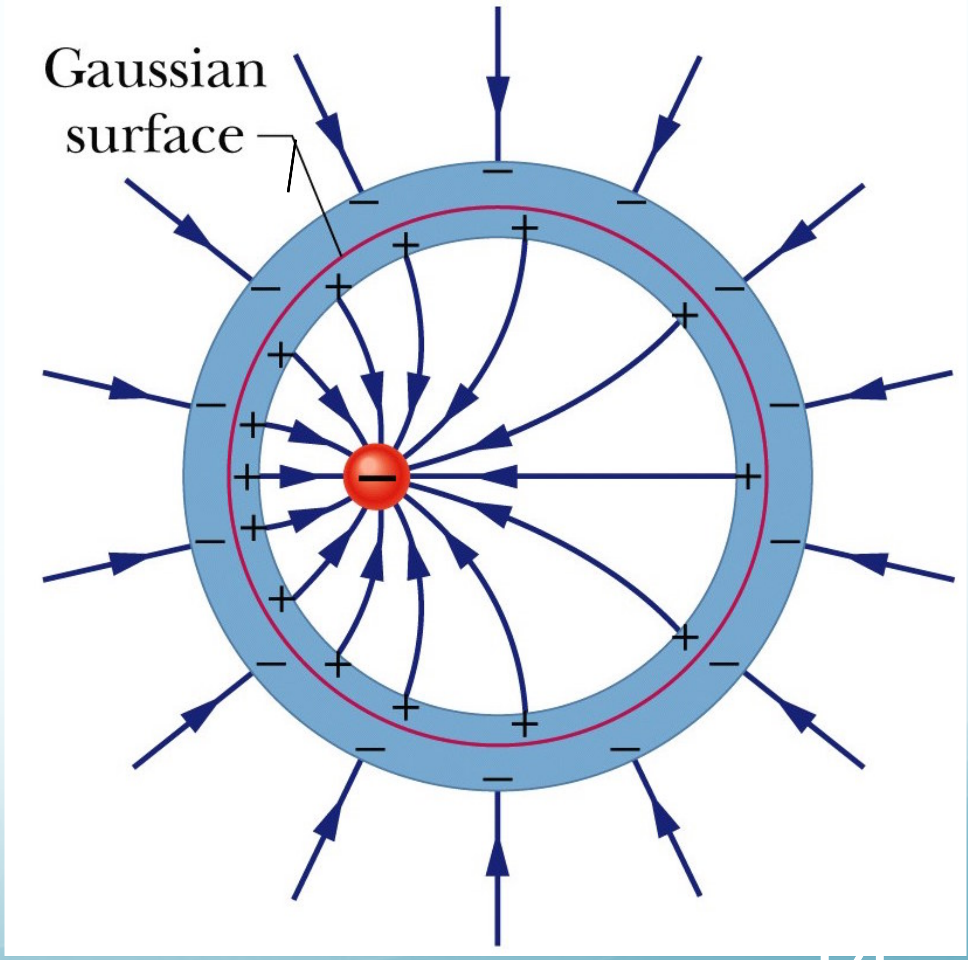
Summary of Conductors and Electric Fields







Faraday cages also shield the outside from fields on the inside. If the charge in the cavity were moved around, the field inside would be complicated and time-varying, but that information would not make it outside.



Properties of Conductors

Summary:

- 1. The electric field is zero inside a conductor. – Static Case
- 2. All excess charge is distributed over the outside surface.

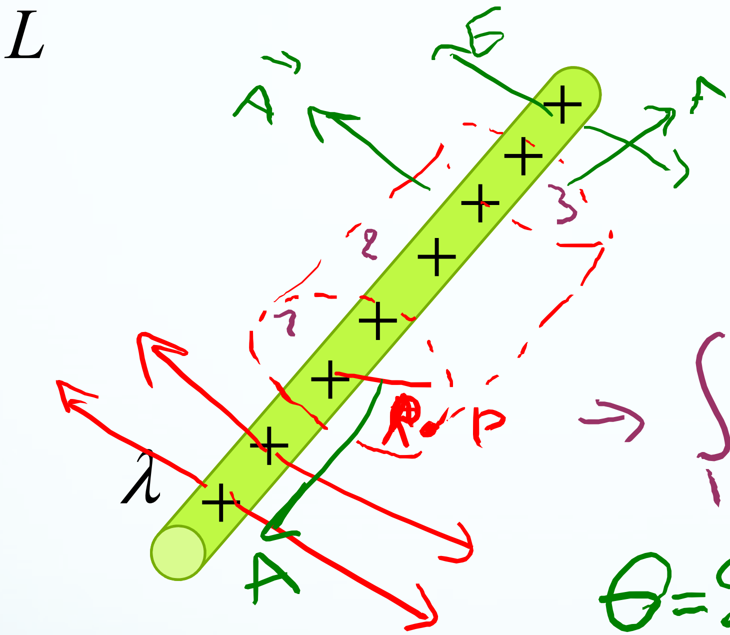
  Inside, a conductor is neutral.

- 3. The electric field outside a conductor is parallel to the area vector (perpendicular to the surface) at each point and has a magnitude **E** = σ/ε_0
- 4. The charge density is greatest where the radius of curvature is smallest.

23-4 and 23-5

Electric field of a long, charged wire

$$\Phi_e = \oint \vec{E}.d\vec{A} = \frac{\cancel{Q_{in}}}{\varepsilon_0} \quad q_{enc}$$



$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

$$\rightarrow \int_1 + \int_2 + \int_3 = \oint \vec{E}\cdot d\vec{A}$$

$\theta = 90^\circ$ $\quad \theta = 0$ $\quad \theta = 90$

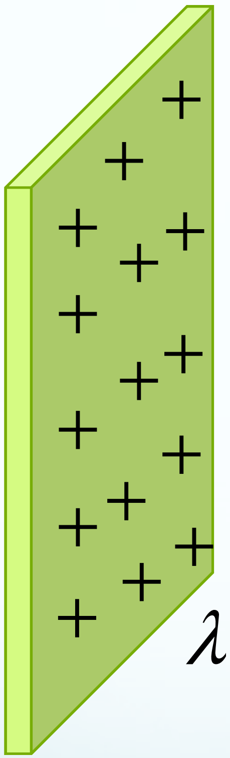
$Q_{in} = ?$

$$\rightarrow \int_2 E\,dA\cos 0 = \frac{q_{enc}}{\varepsilon_0} \rightarrow E\int dA = \frac{q_{enc}}{\varepsilon_0}$$

$$\rightarrow EA = \frac{q_{enc}}{\varepsilon_0} \rightarrow E_{wire} = \frac{\lambda}{2\pi\varepsilon_0 r}$$

will continue next section

Electric field of a plane of charge



$$\Phi_e = \oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$$

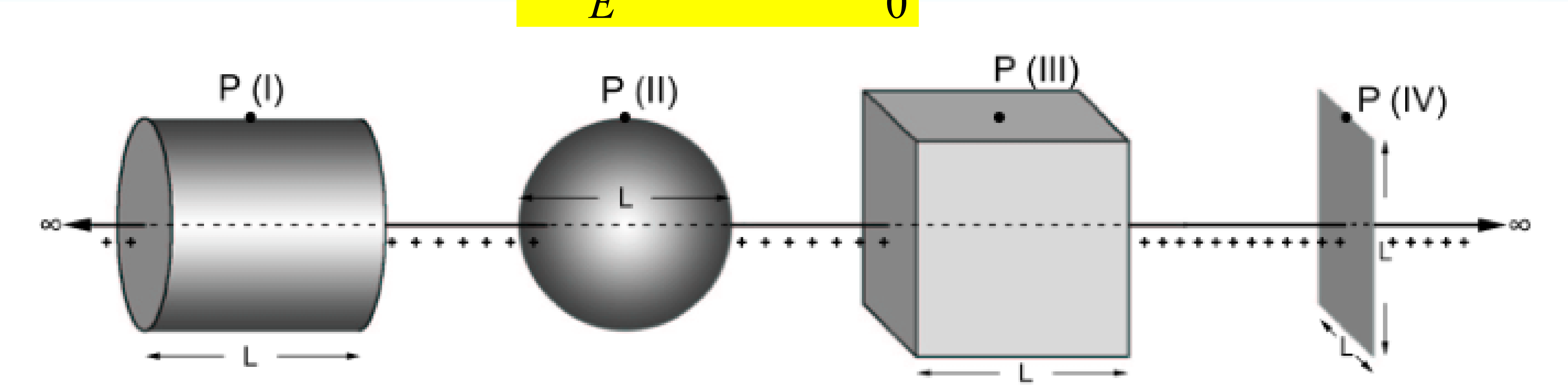
$$Q_{in} = ?$$

$$E_{plane} = \frac{\sigma}{2\varepsilon_0}$$

TopHat Question

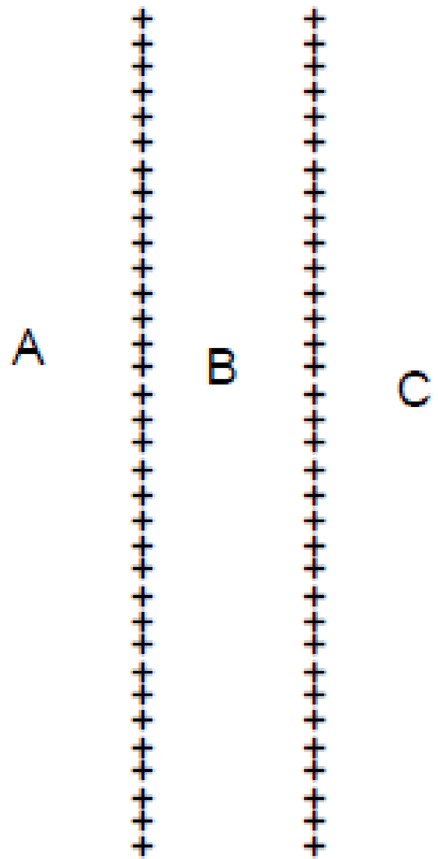
4 surfaces are coaxial with an infinitely long line of charge with a uniform linear charge density = λ. Choose all the surfaces through which

$$\Phi_E = \lambda L / \varepsilon_0$$



A) I only
B) I and II only
C) I and III only
D) I, II, and III only
E) All four.

Two infinite planes are uniformly charged with the same charge per unit area σ   If **one plane only** were present, the E-field magnitude due to the **one** plane would be E. With both planes in place, the E-field magnitude in region B has magnitude:



A: zero   B: E   C: 2E

D: depends on exact position.

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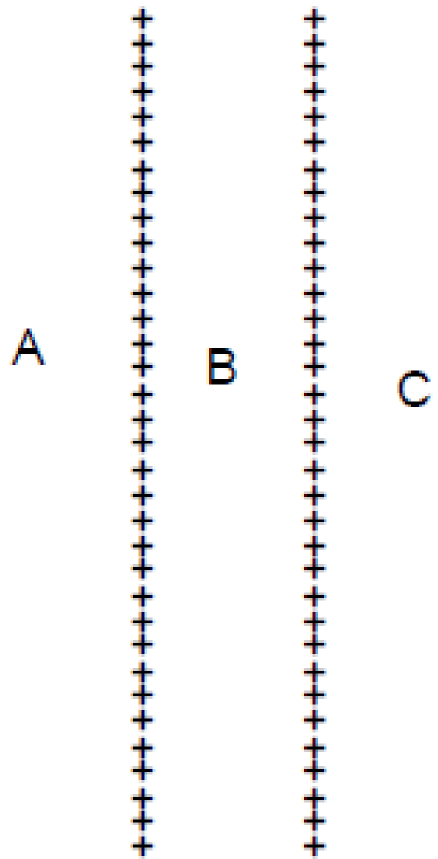

A: zero B: E C: 2E

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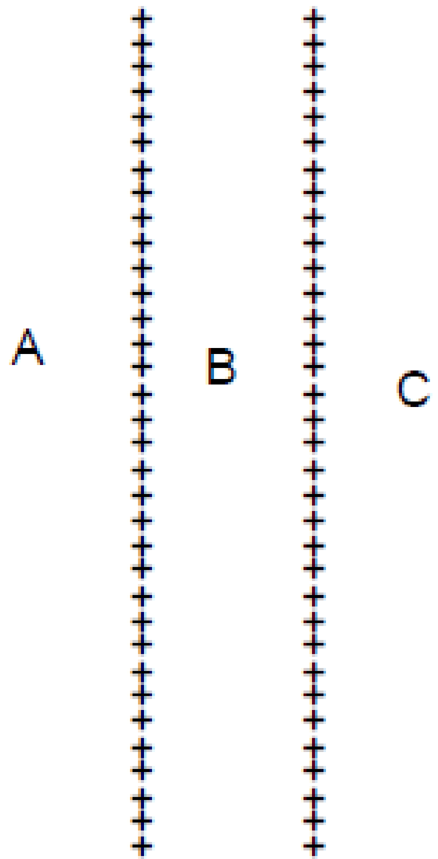
Two infinite planes are uniformly charged with the same charge per unit area σ . If **one plane only** were present, the E-field magnitude due to the **one** plane would be E.

If both planes are present then

The E-field magnitude in region C has magnitude:

A: zero　　B: E　　C: 2E

D: depends on exact position.



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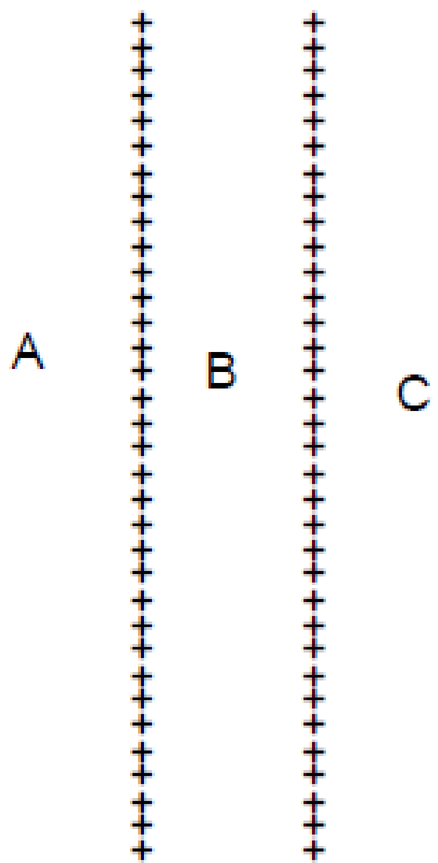

If both planes are present then

The E-field magnitude in region C has magnitude:

A: zero

B: E

C: 2E

D: depends on exact position.

This section we talked about:

Chapter 23.3-4

See you on Wednesday