# Lecture 4:
# Electric field lines

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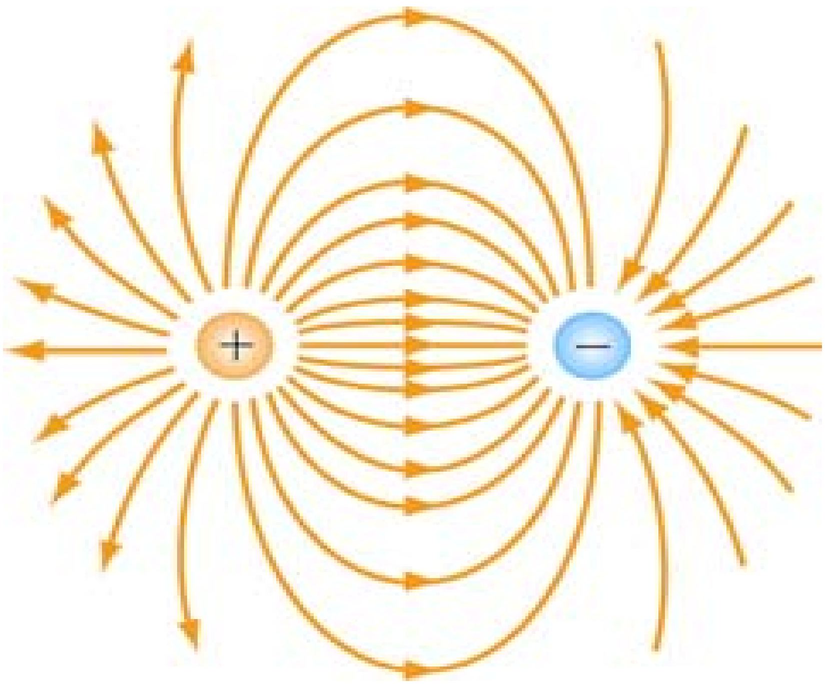
# How do electric fields distribute in space?

- A fundamental aspect in electromagnetism is to understand the *geometry* of the problem (general to any field theory).

- A useful technique is to draw *field lines.*

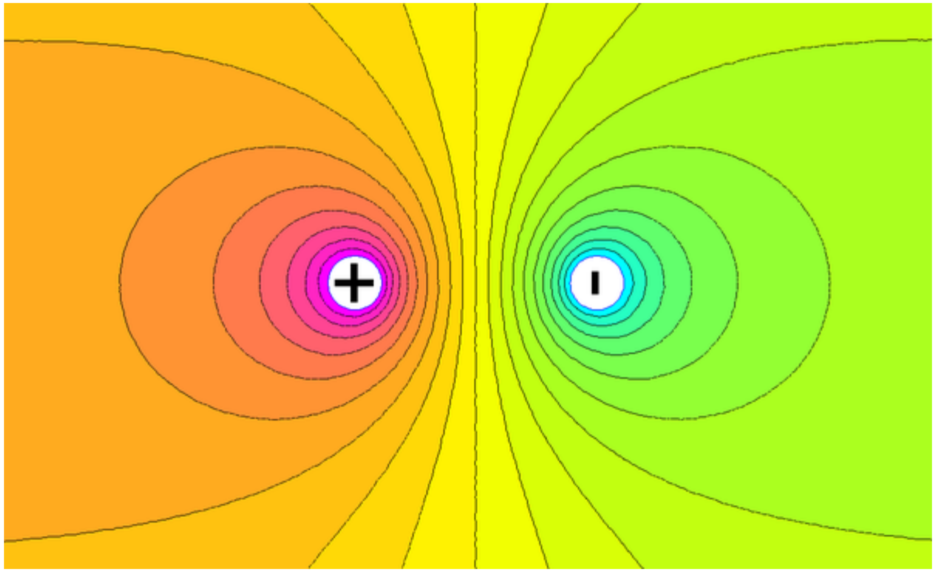



**ELECTROSTATIC FIELDS:**

- field lines never cross
- always a start and a finish (no loops)
- always pointing from a positive to a negative charge
- the more packed the lines, the stronger the field

# How do potentials distribute in space?

- Remember that $\vec{E} = -\nabla\Phi$

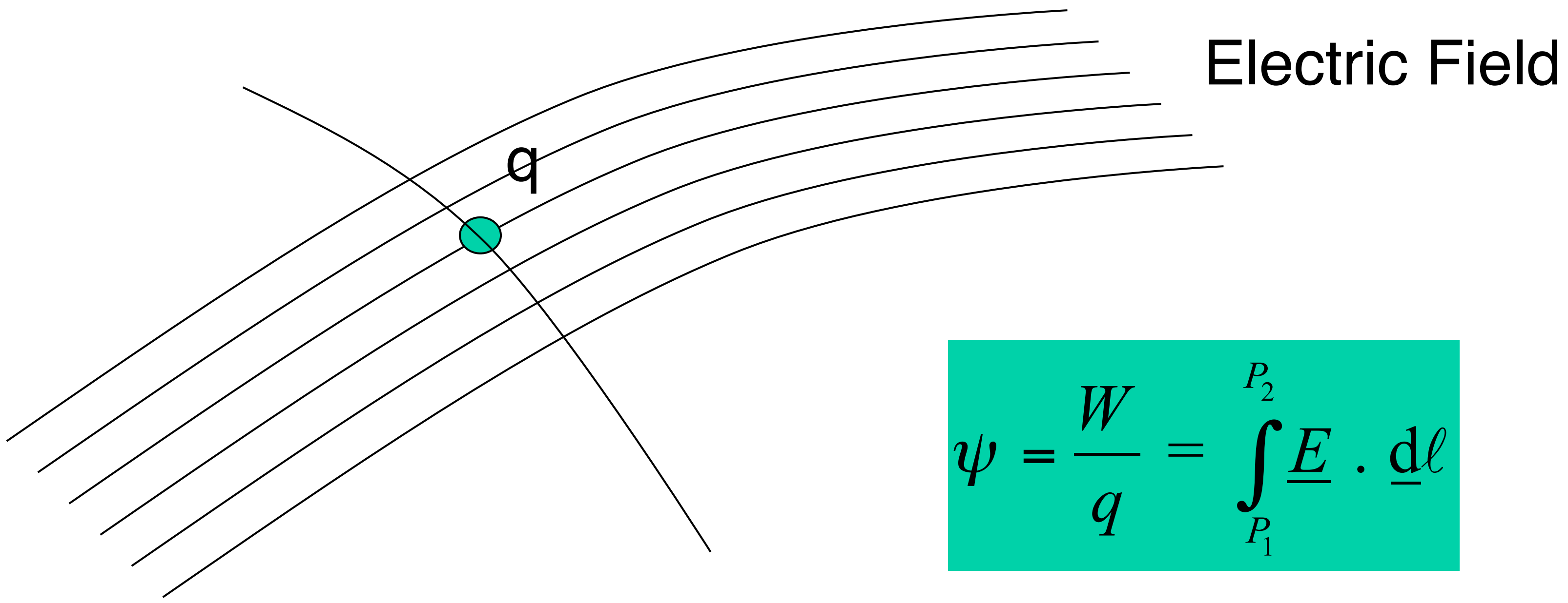


**POTENTIAL**

- field lines never cross
- always in loops
- always perpendicular to the electric field lines
- the more packed the lines, the stronger the potential

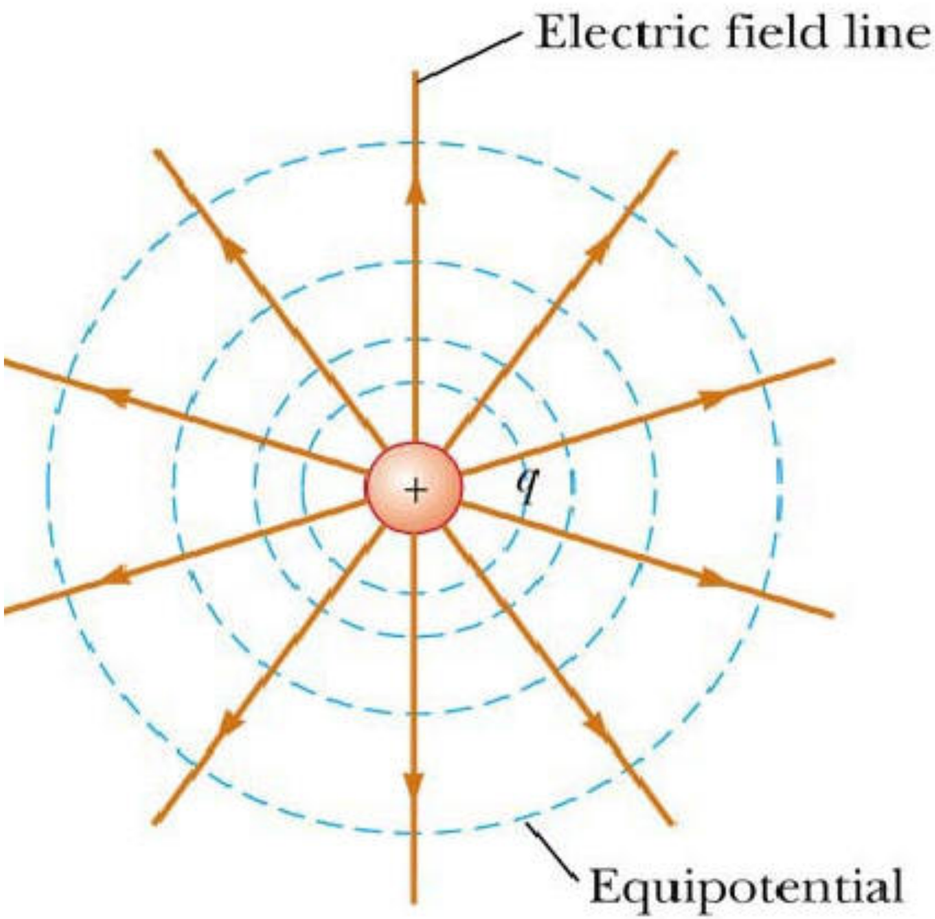
- The potential lines are, rather, surfaces (imagine the picture above in 3D).
- These are called *equipotential surfaces*

# Examples



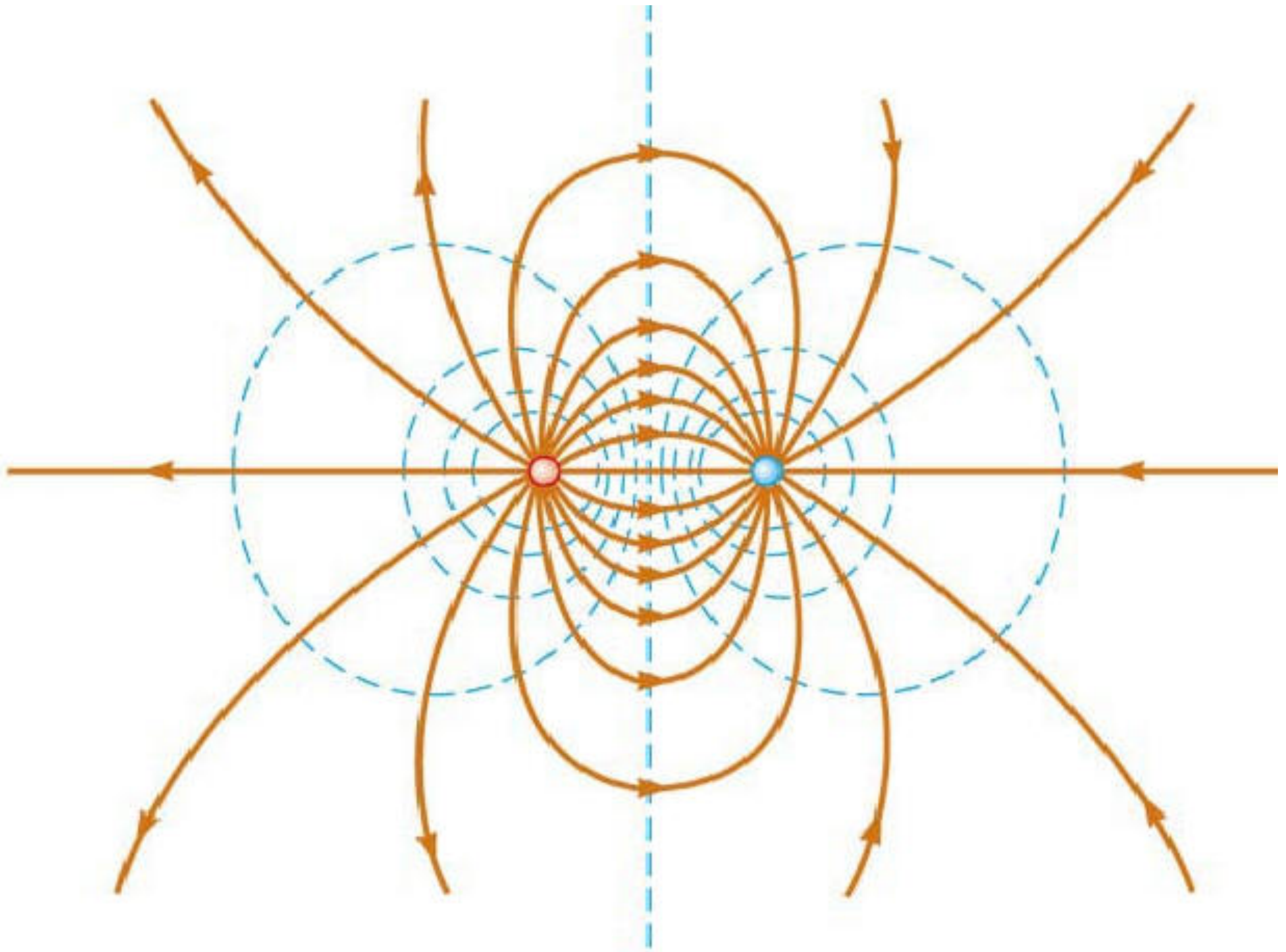

$$\psi = \frac{W}{q} = \int_{P_1}^{P_2} \underline{E} \cdot \underline{\mathrm{d}}\ell$$

# Examples




(a)

# Examples



(b)

# Field lines from materials

**CONDUCTOR:** a material that allows for current and heat flow. Availability of electrons in the conduction band

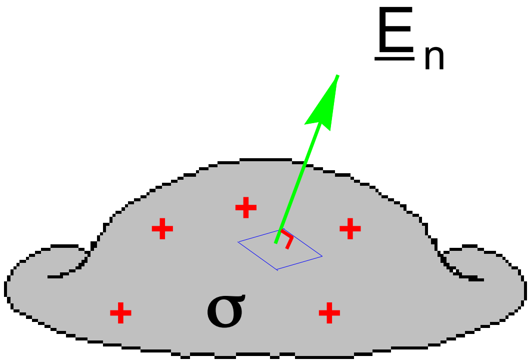


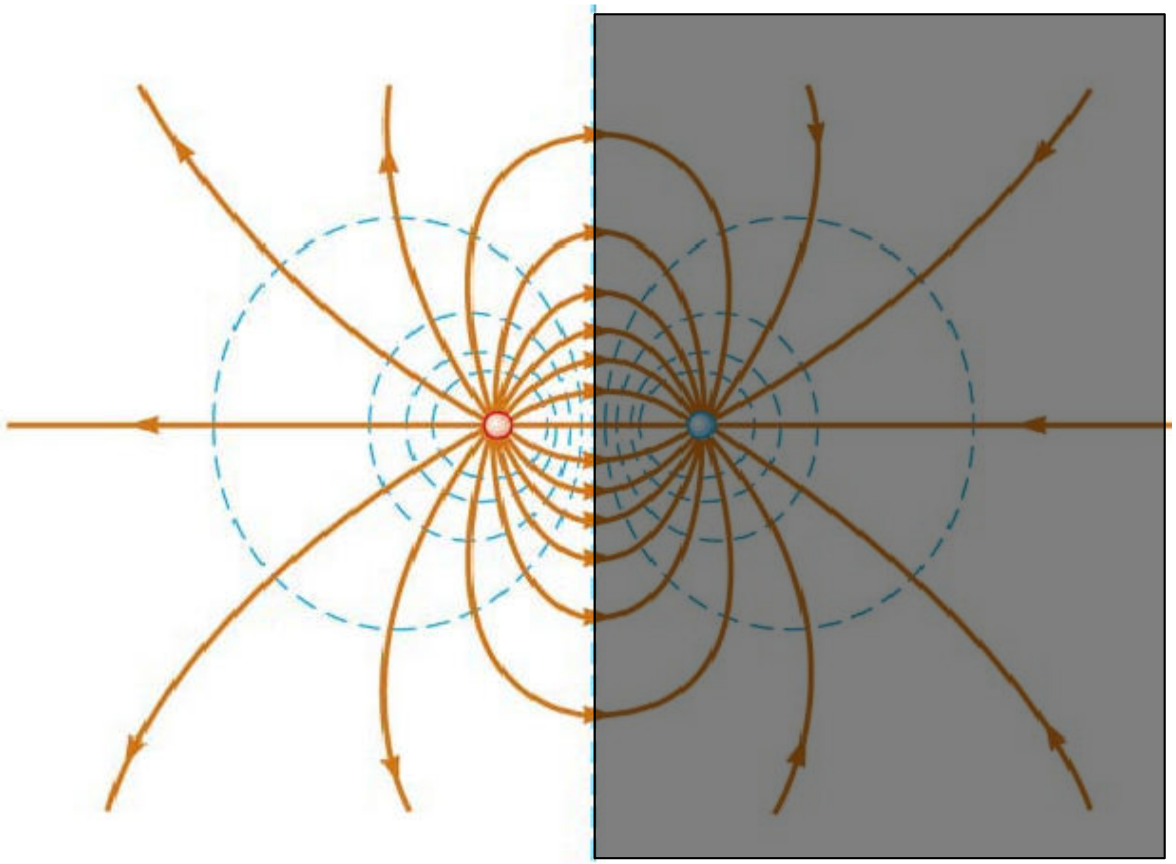

Fig 31

- electric fields NOT allowed inside it
- free charges always distribute on the surface

- Field lines always perpendicular to the surface

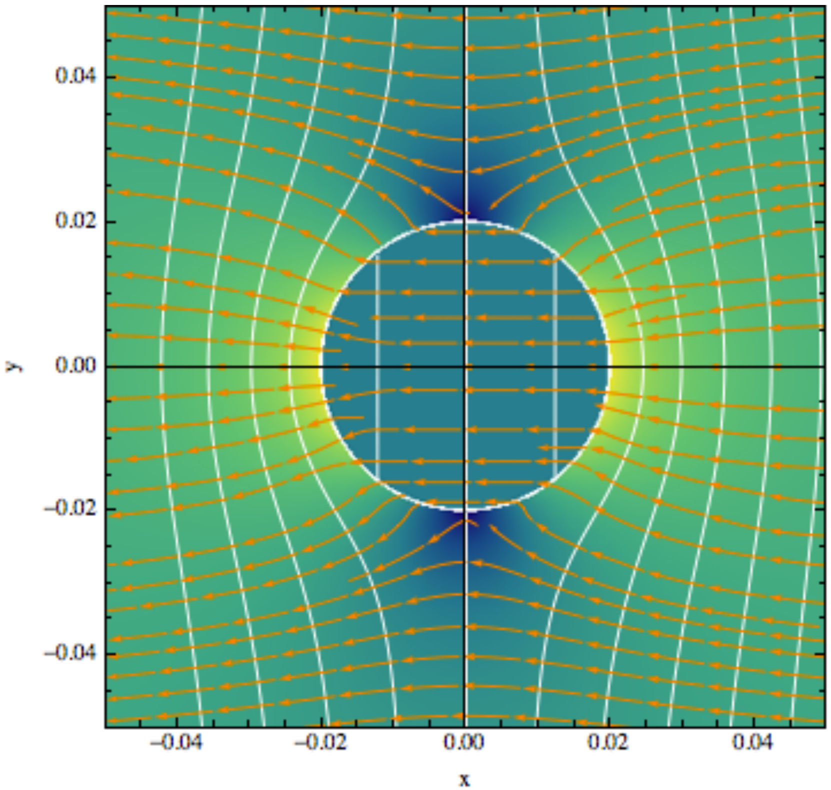
# Mirror charges

A useful trick if we want to draw field lines between a charge and a conductor is to imagine there is a virtual charge that is the mirror image of the real charge



# Field lines from materials

**DIELECTRIC:** poor (ideally none) conduction of currents and heat.
Empty conduction band

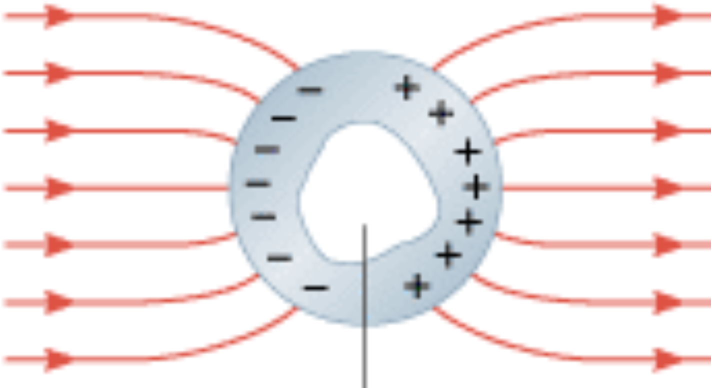


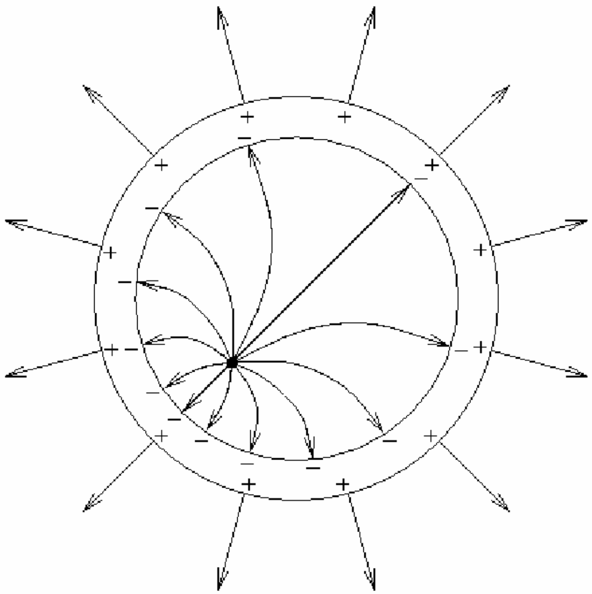

- Electric fields allowed inside it
- Generally, change in direction (will see more on this, later)
- Continuous field lines but with kinks (i.e., discontinuous in first derivative)

# Field lines from a hollow material

Conducting sphere

Field inside is 0 (gauss surface)

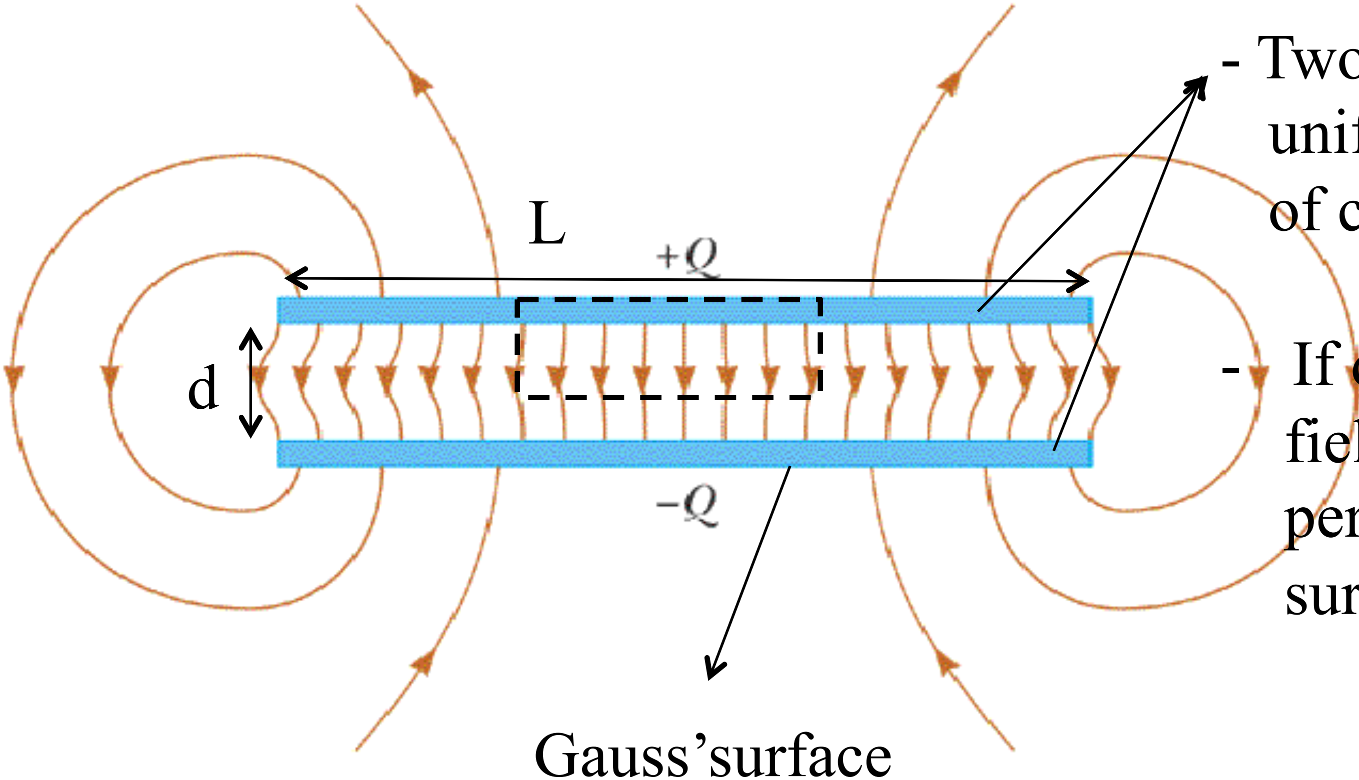




*A conductor is capable of completely screening an external electric field*

*Placing a charge inside it induces charge being accumulated on the inner surface and an equal amount on the outer surface. Seen from afar, equivalent to the field generated by a point-like source*

# Example: a capacitor




- Two conductors imply uniform distribution of charge ($\sigma$).

- If $d \ll L$ the electric field lines are almost perpendicular to the surfaces.

Total Charge inside the Gauss' surface: $Q = \sigma S$
Gauss' law: flux of $E = ES = Q/\varepsilon_0$

Combining the two: $\boxed{E = \sigma/\varepsilon_0}$ *(constant!)*