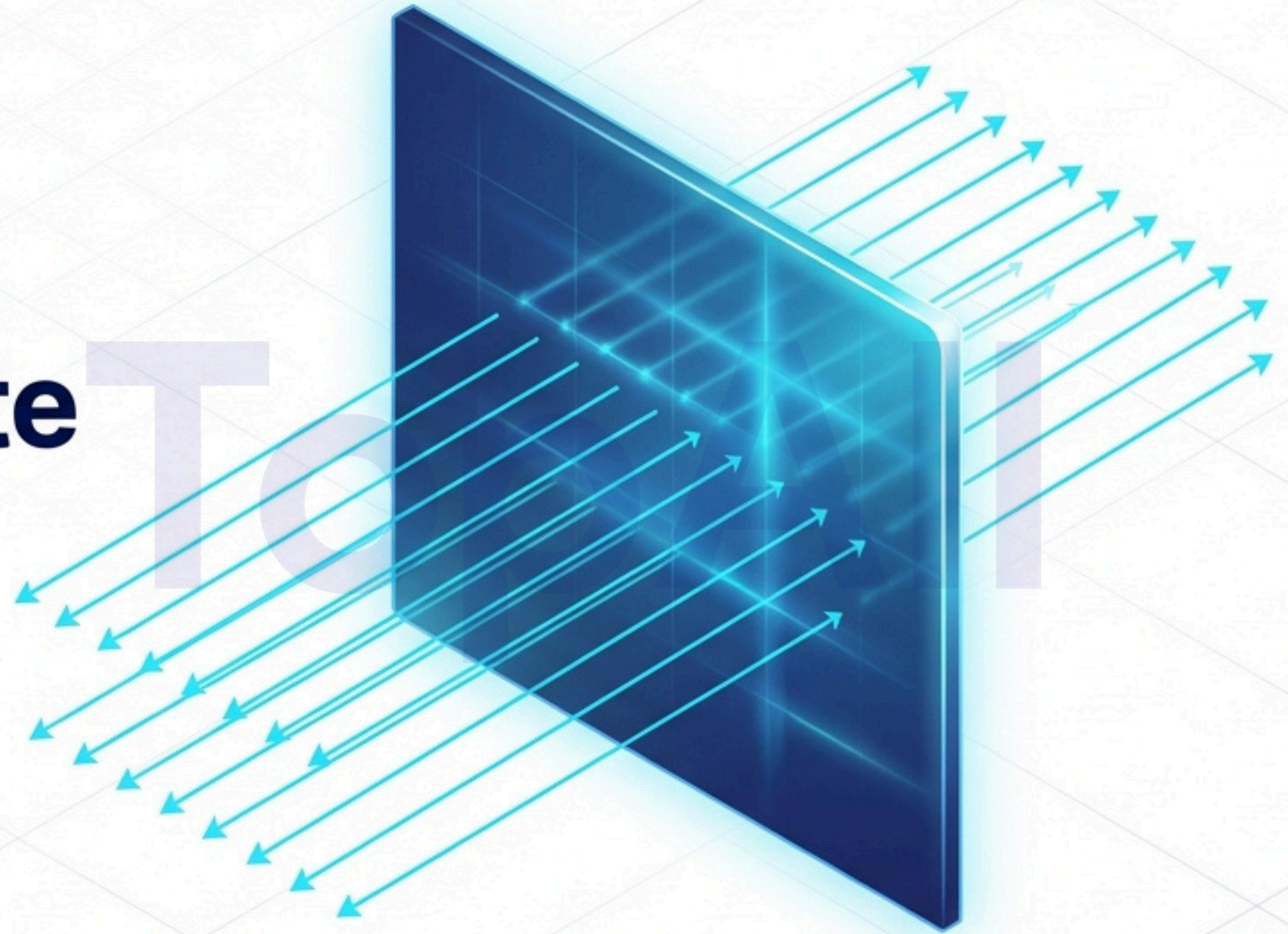
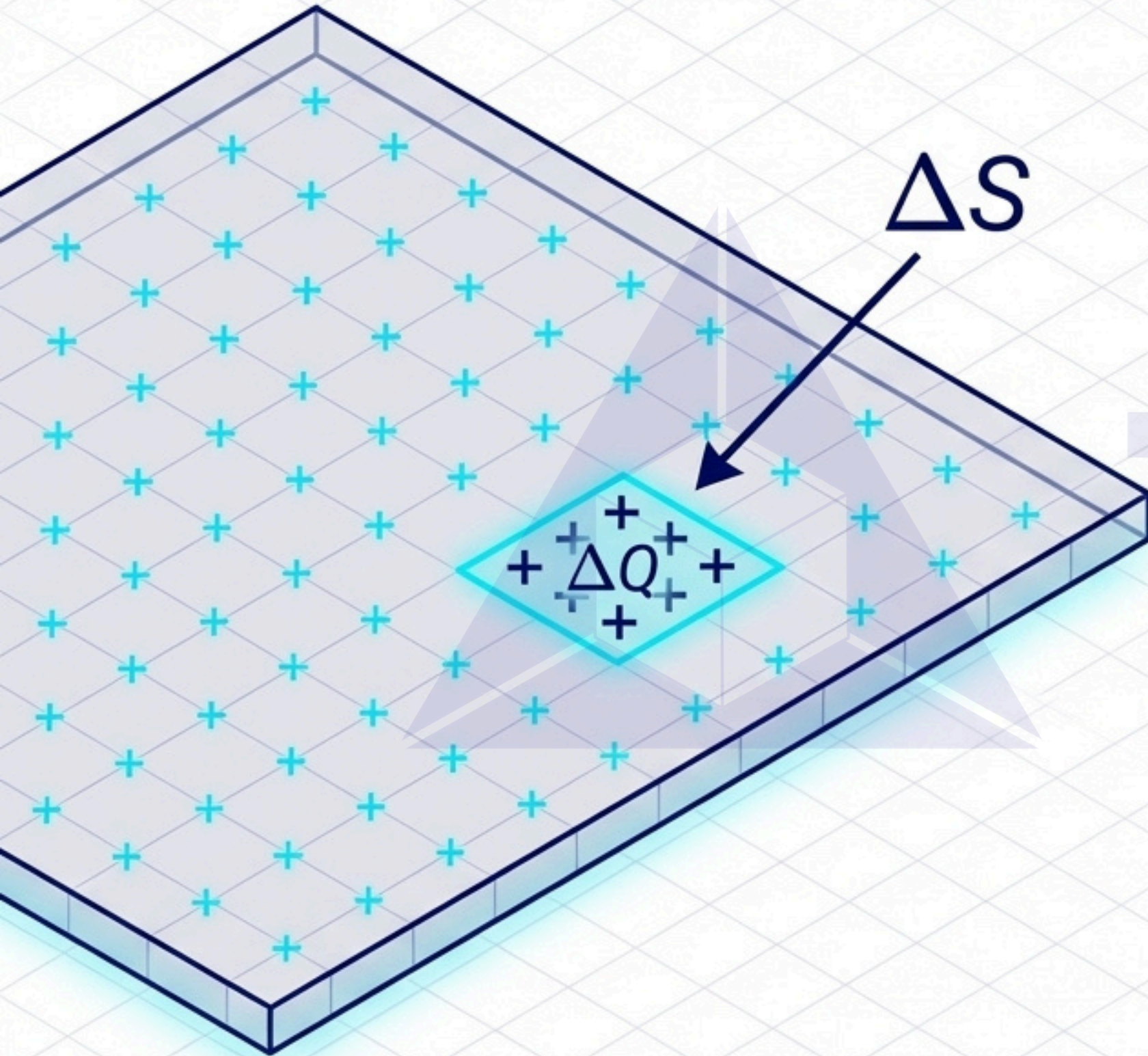


Chapter 1: Electric Charges and Fields | 1.14.2

Electric Field Due to an Infinite Plane Sheet

Applying Planar Symmetry
and Gauss's Law





Surface Charge Density

For a continuous 2D charge distribution, we define the macroscopic **surface charge density** as the charge per unit area.

$$\sigma = \frac{\Delta Q}{\Delta S} \text{ (Units: C/m}^2\text{)}$$

Planar Symmetry

Because the sheet is infinite, it looks exactly the same in all directions from any observation point P. This absolute symmetry dictates the geometric behavior of the resulting electric field.



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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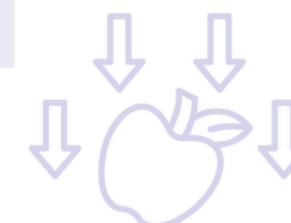
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Key Highlights

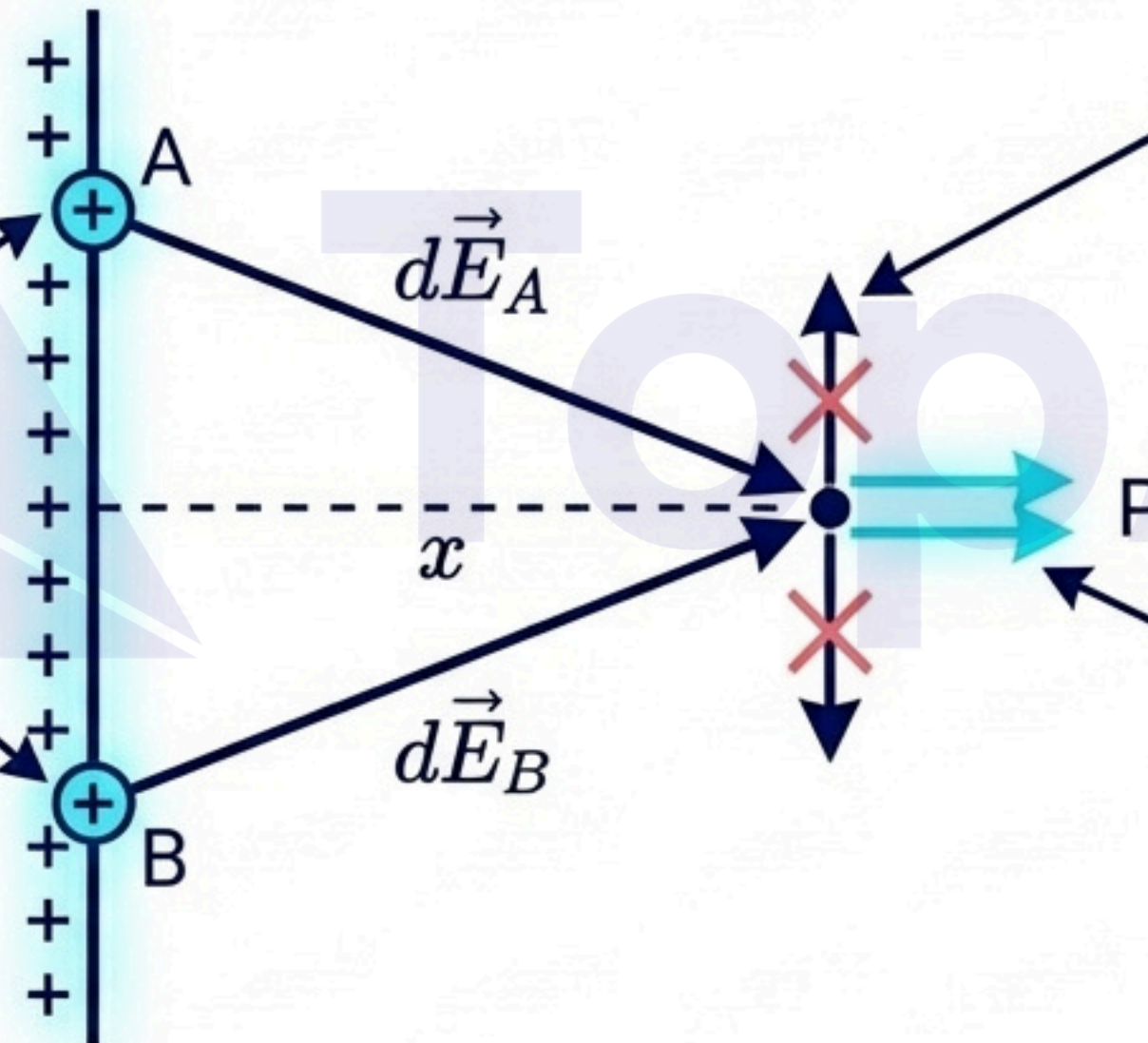
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Why the Field is Normal to the Plane

Vector Cancellation

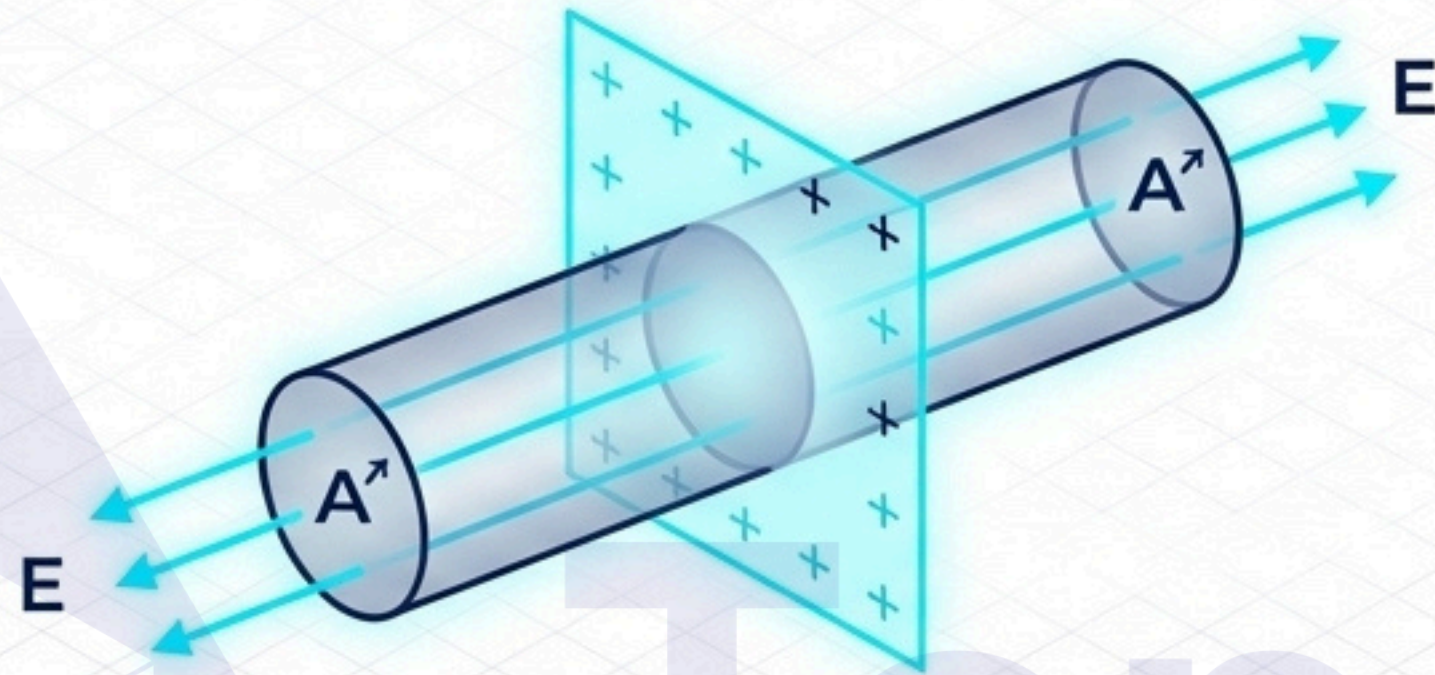
Symmetrical charge pairs exist for every point on the infinite sheet.



Parallel components (E_y , E_z) perfectly cancel out.

Only the normal component (E_x) survives. Therefore, **E** is **strictly perpendicular** to the sheet.

The Pillbox Gaussian Surface



Left Cap (Surface 1)



E and ΔS are parallel.

$$\theta = 0^\circ \rightarrow \Phi_1 = EA$$

Flux Breakdown Matrix

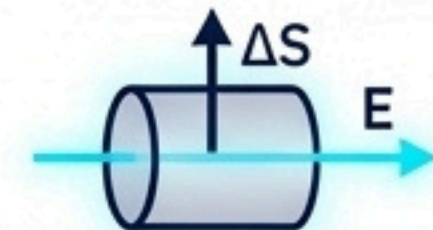
Right Cap (Surface 2)



E and ΔS are parallel.

$$\theta = 0^\circ \rightarrow \Phi_2 = EA$$

Curved Wall (Surface 3)



E and ΔS are perpendicular.

$$\theta = 90^\circ \rightarrow \Phi_3 = 0$$

$$\text{Total Flux } (\Phi_{\text{net}}) = EA + EA + 0 = 2EA$$

Field Result & Distance Independence

The Derivation

Step 1:
Gauss's Law

$$\Phi_{\text{net}} = \frac{q_{\text{enclosed}}}{\epsilon_0}$$



Step 2:
Substitute
knowns

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

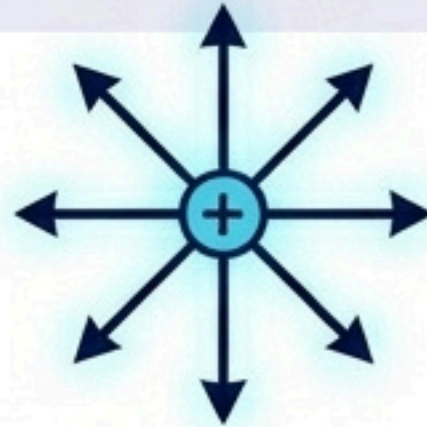


$$E = \frac{\sigma}{2\epsilon_0}$$

Vector Form: $E = \left(\frac{\sigma}{2\epsilon_0}\right) \hat{n}$

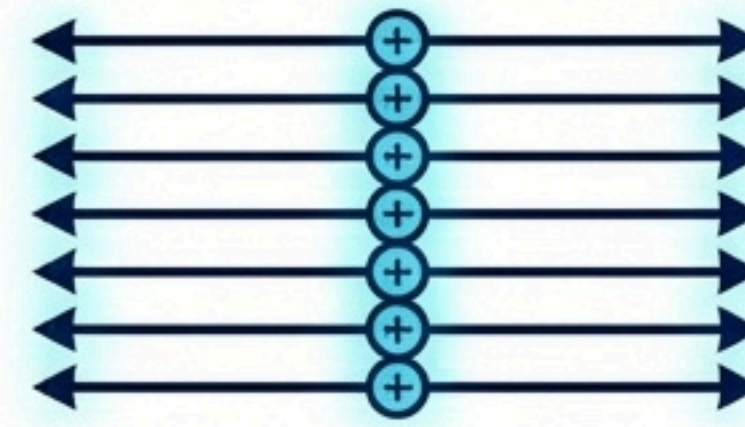
Why is it constant?

Point Charge (2D Positive Point)



Diverging Lines = Field density spreads out.
Field weakens with distance ($1/r^2$).

Infinite Sheet (2D Vertical Line of Charges)



Parallel Lines = Field density never changes.
E is completely independent of distance r .

Summary & Practice

✓ Key Takeaways

1. Field magnitude is exactly $E = \frac{\sigma}{2\epsilon_0}$.
2. The field is completely uniform (independent of distance r).
3. Direction is defined by normal vector $\hat{n}$ (outward if $\sigma > 0$, inward if $\sigma < 0$).
4. This approximation is highly valid in the middle regions of large finite sheets, safely ignoring edge effects.

⚠ EXAM TRAP

Do not confuse a thin non-conducting sheet with a thick conducting plate! A thick conductor has charge on both outer surfaces, doubling the enclosed charge inside a pillbox.

Thin Sheet:

$$E = \sigma / 2\epsilon_0$$

vs.

Thick Conductor:

$$E = \sigma / \epsilon_0$$

Practice: Check Your Understanding

Q: An electron is placed 10 cm away from an infinite plane sheet of charge. It is then moved to 20 cm away. How does the electrostatic force on the electron change?

Reveal Answer

A: It remains entirely unchanged. Force $F = qE$, and the electric field E is independent of distance.



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