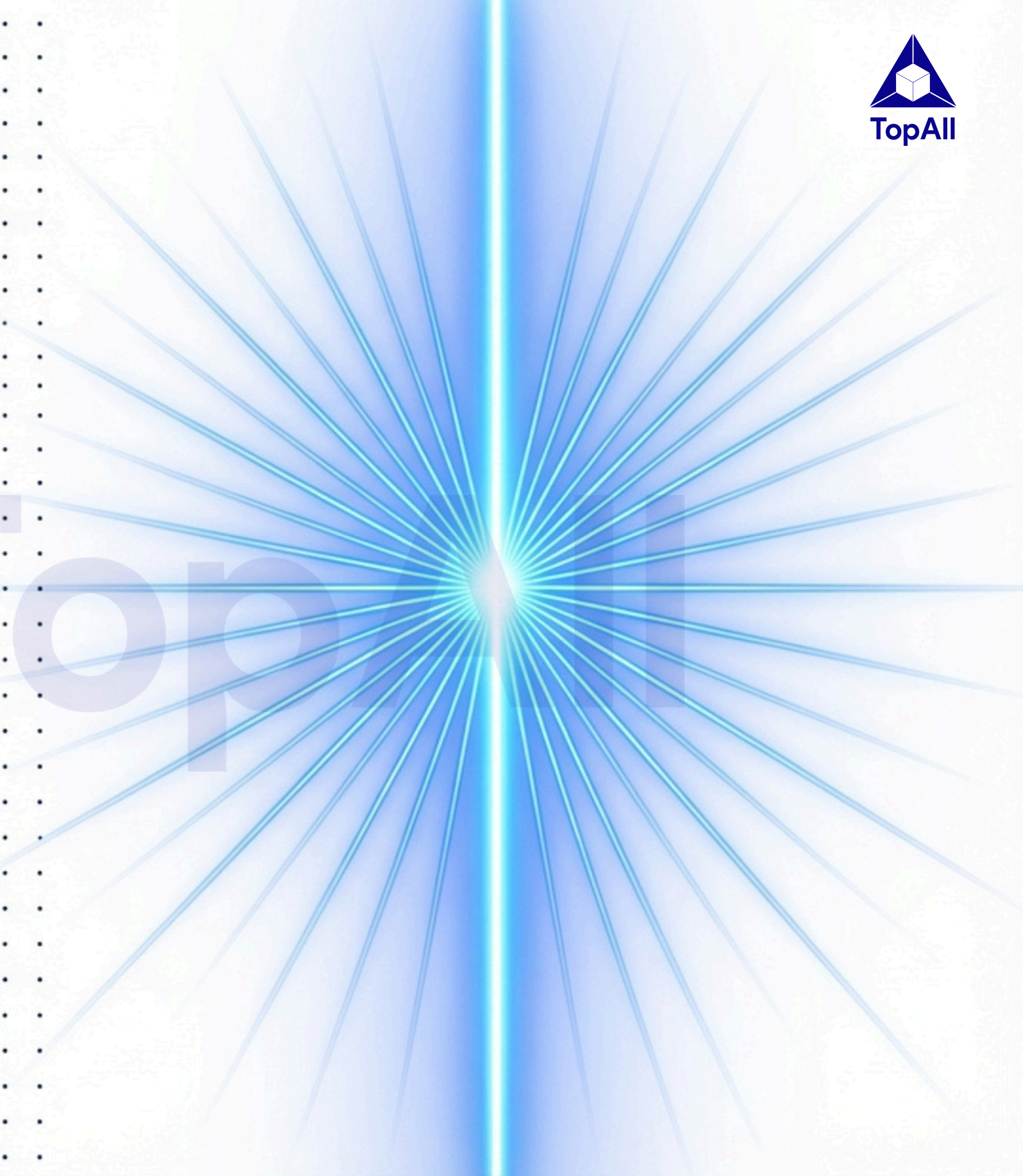


NEET/JEE Core Concept | Electrostatics

Field Due to an Infinitely Long Straight Uniformly Charged Wire

Applying Gauss's Law to master cylindrical symmetry.

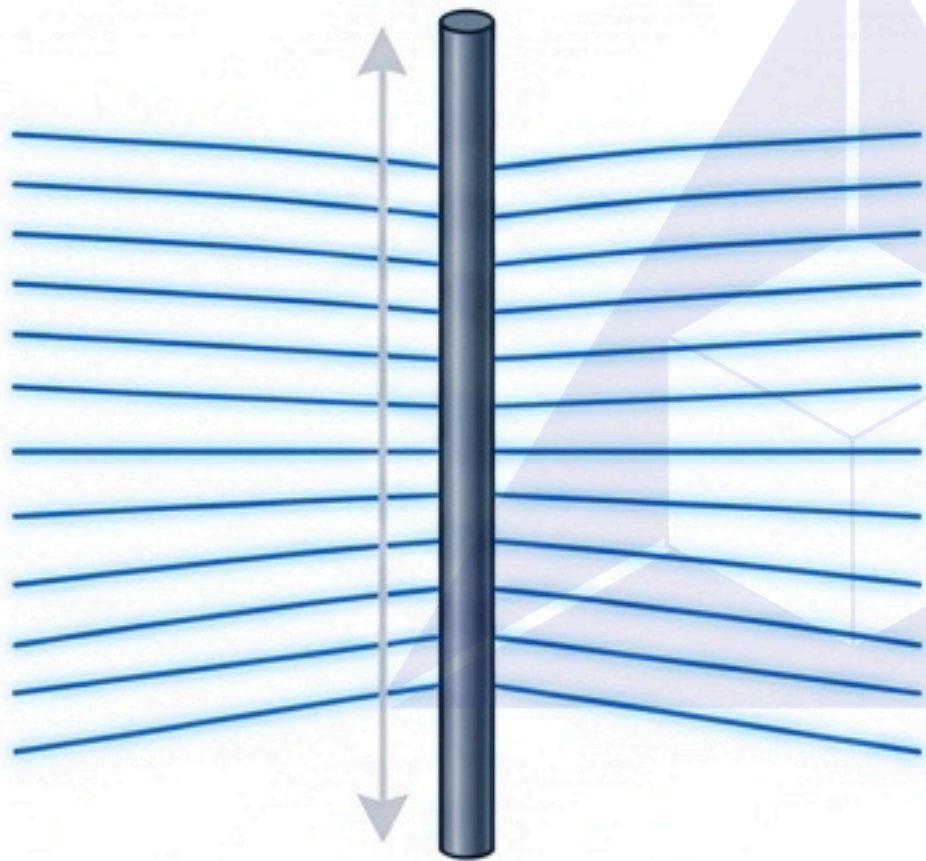
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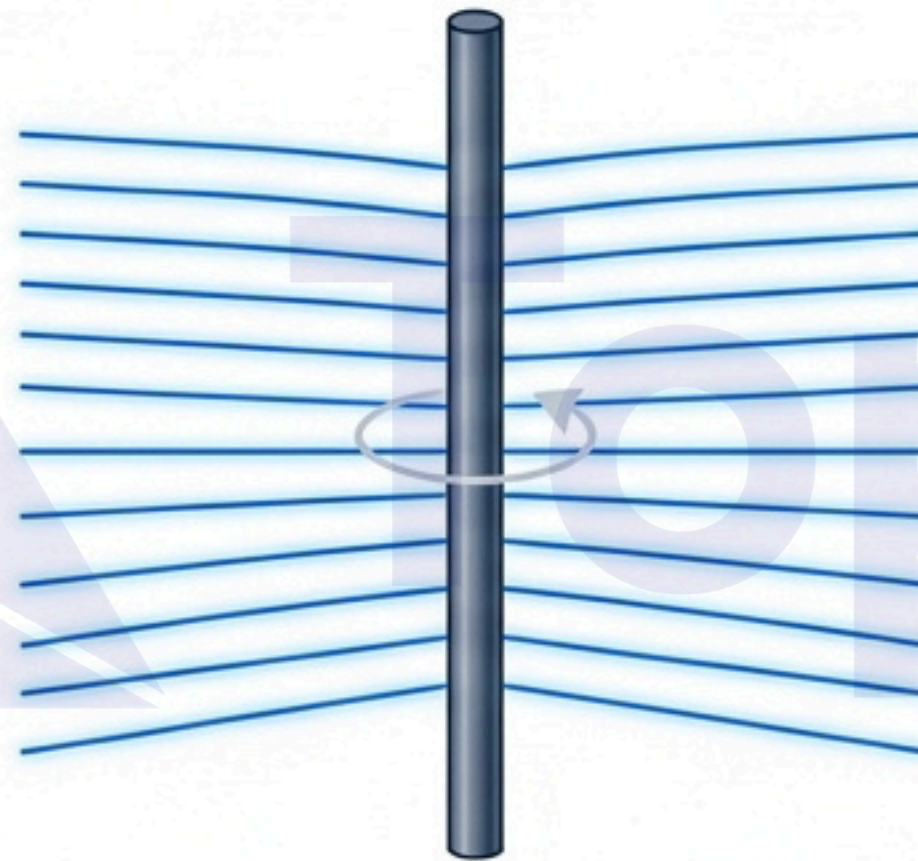
The Power of Infinite Symmetry

An infinitely long wire with uniform linear charge density λ has no edges.

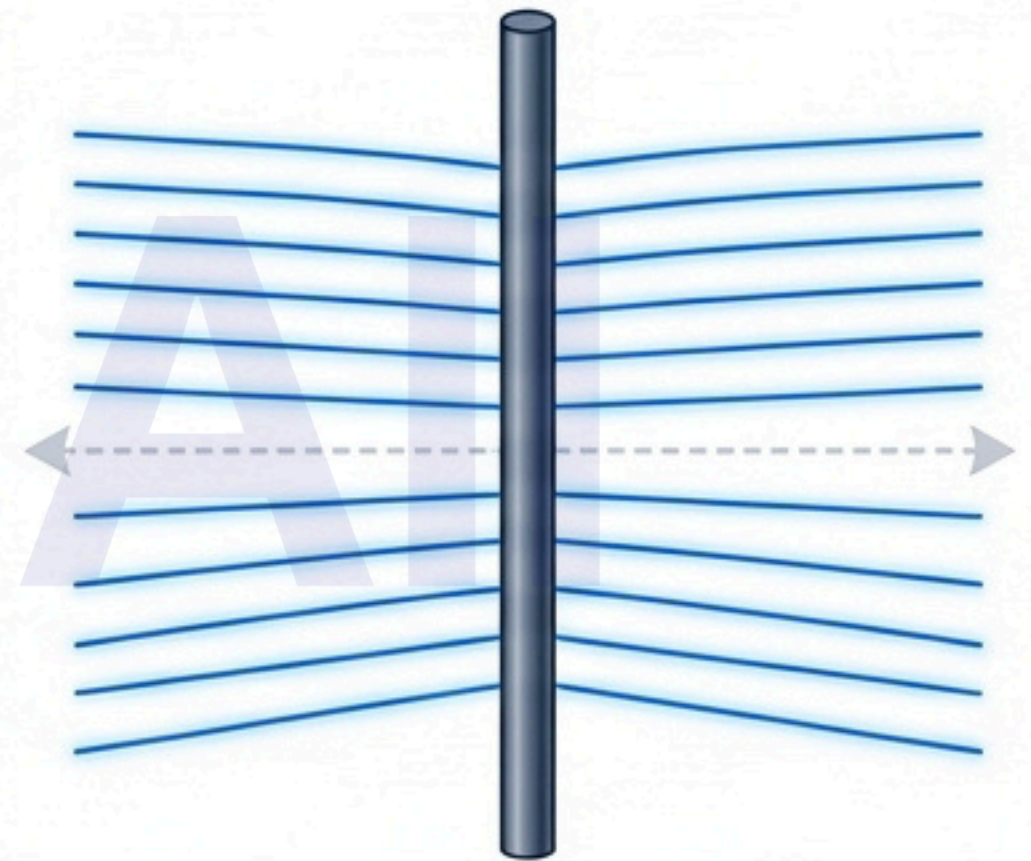
1. Translation



2. Rotation



3. Reflection



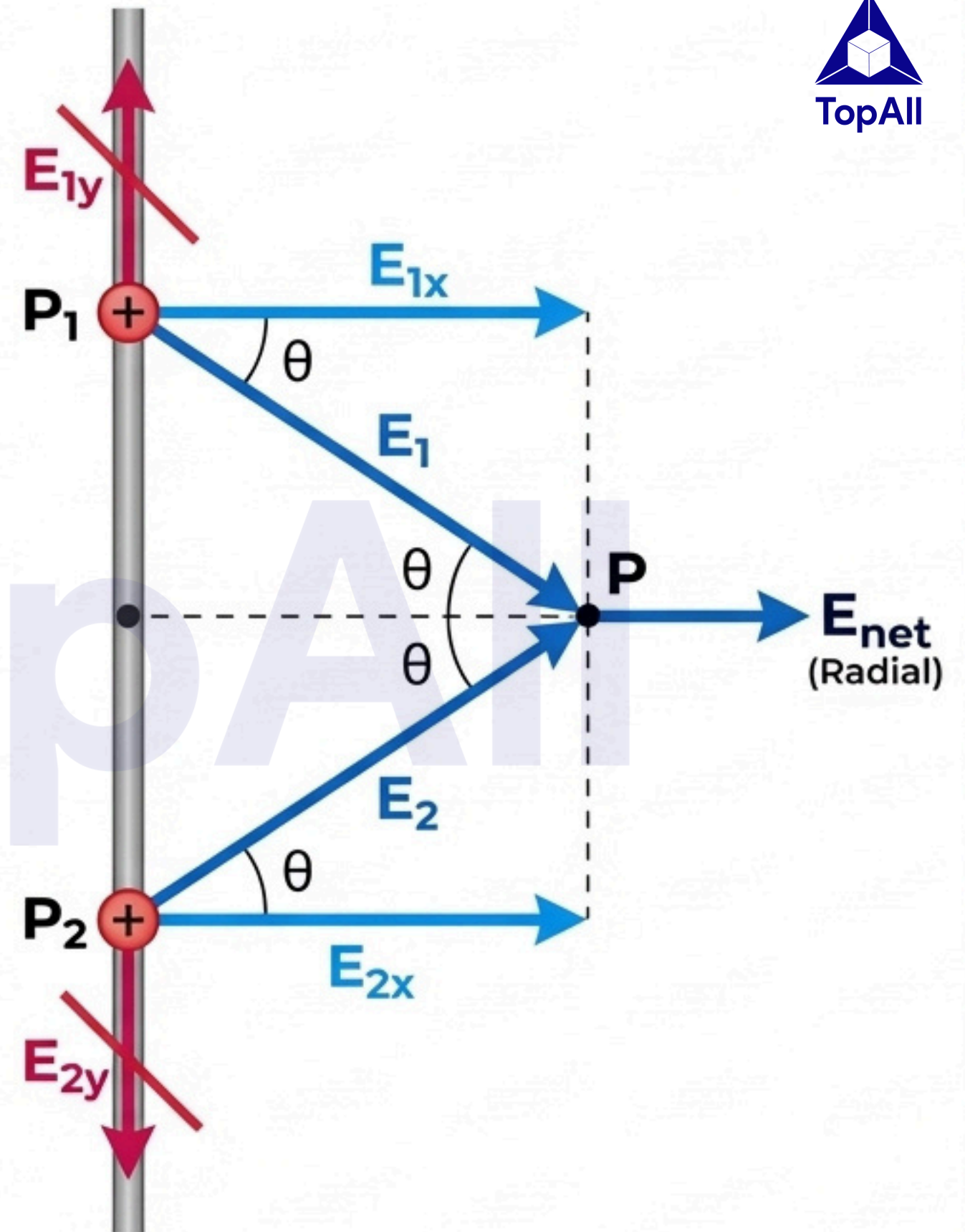
Because the physical environment looks identical under translation, rotation, and reflection, the electric field magnitude can only depend on one variable: the perpendicular radial distance, r .

Why the Field is Exclusively Radial

For every charge element pushing the field up, there is a perfectly symmetric element pushing it down.

$$\sum E_{\text{parallel}} = 0$$

The parallel components cancel perfectly. The resultant electric field is strictly radial.





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$$E=mc^2$$



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Key Highlights

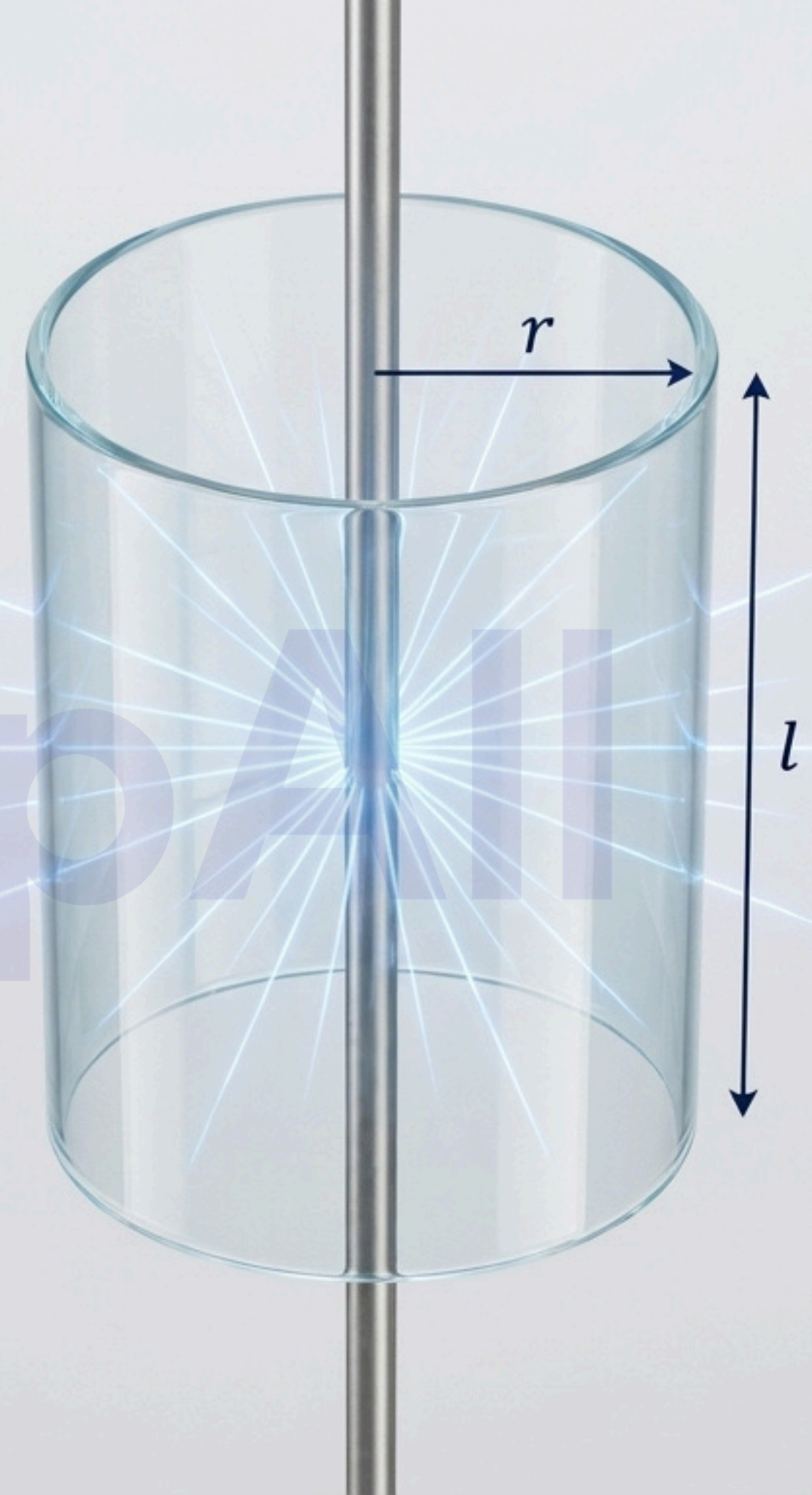
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Choosing the Bounding Box

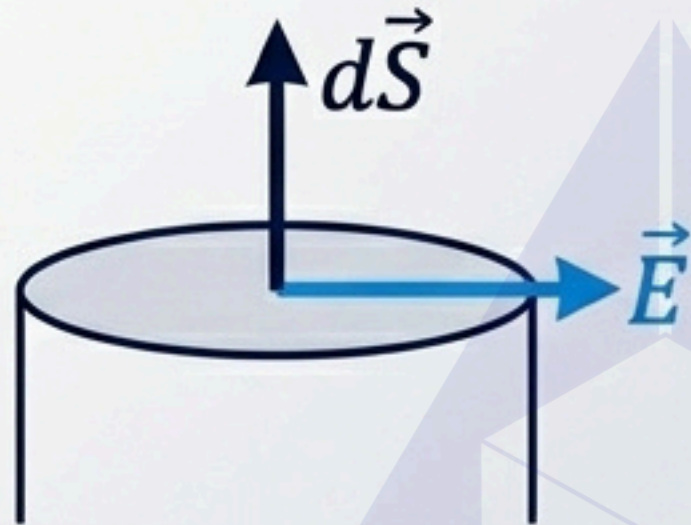
- To use Gauss's Law without complex integration, we need a surface where the electric field is either perfectly parallel or perfectly perpendicular to the area vector $d\vec{S}$.
- A cylindrical Gaussian surface perfectly envelopes the radial field lines.

Enclosed Charge: $q_{\text{enclosed}} = \lambda l$



Flux Calculation Matrix ($\oint \vec{E} \cdot d\vec{S}$)

Top Circular Cap

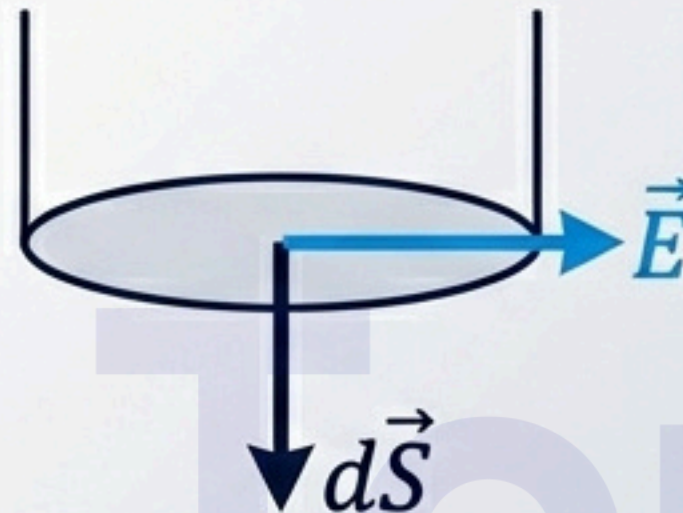


$$\vec{E} \perp d\vec{S} \rightarrow \theta = 90^\circ$$

$$\cos(90^\circ) = 0$$

$$\Phi_1 = 0$$

Bottom Circular Cap

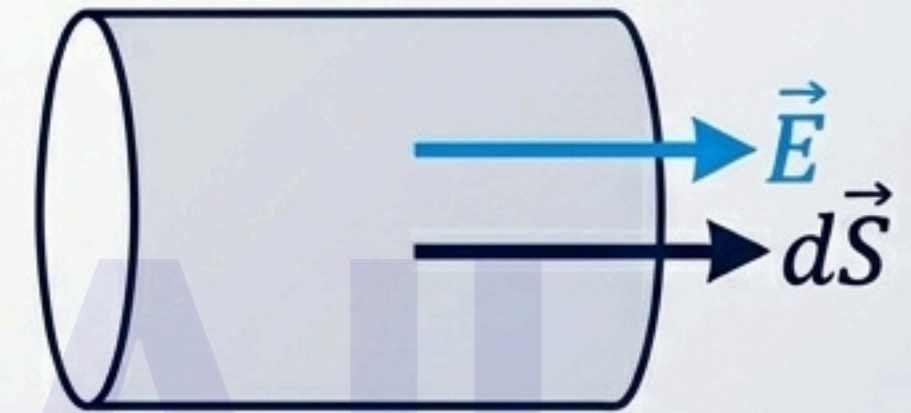


$$\vec{E} \perp d\vec{S} \rightarrow \theta = 90^\circ$$

$$\cos(90^\circ) = 0$$

$$\Phi_2 = 0$$

Unrolled Curved Surface



$$\vec{E} \parallel d\vec{S} \rightarrow \theta = 0^\circ$$

$$\cos(0^\circ) = 1$$

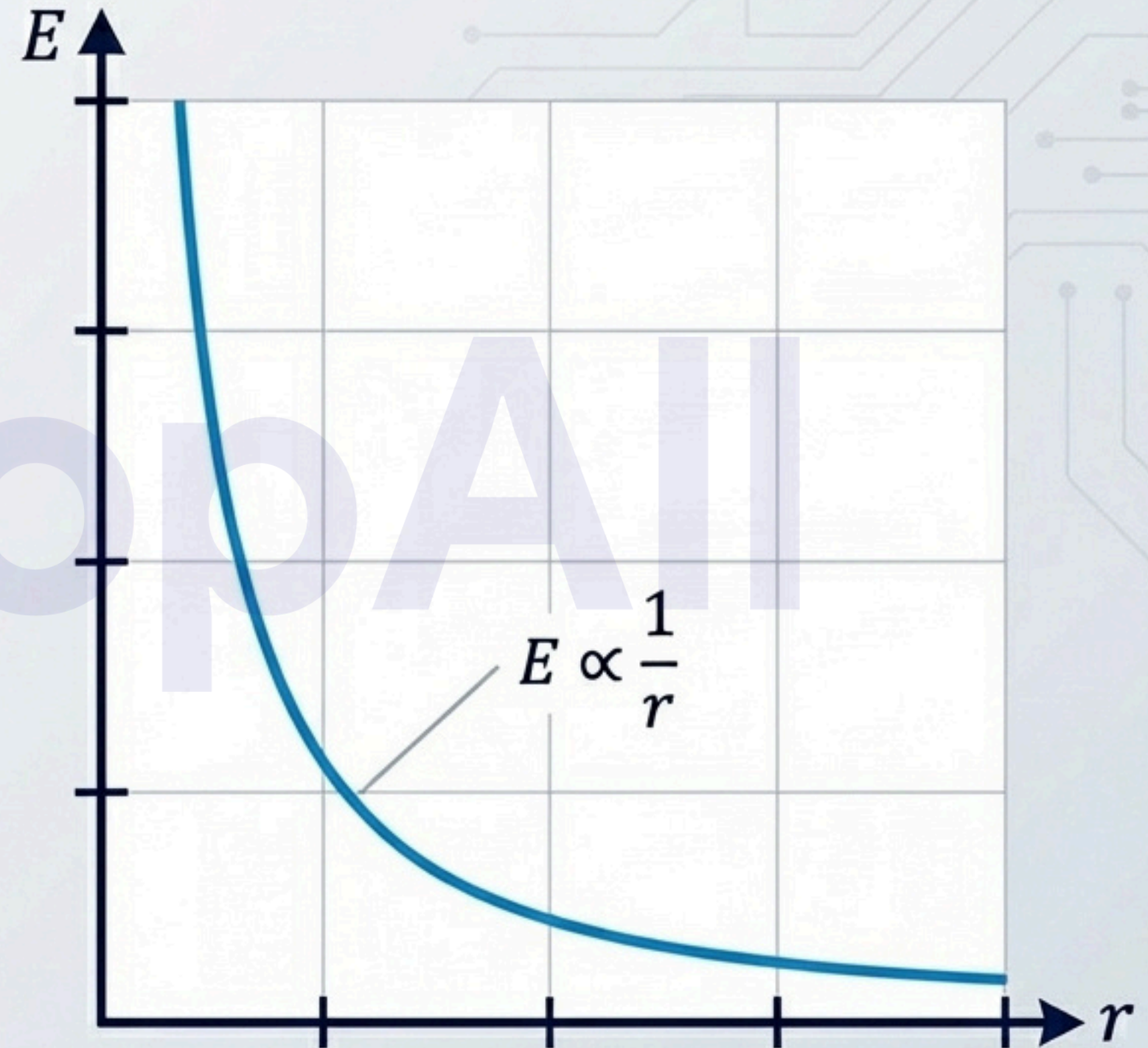
$$\Phi_3 = E(2\pi rl)$$

$$\text{Net Flux } \Phi_{total} = E(2\pi rl)$$

Final Field Result & Properties

- Gauss's Law gives: $E(2\pi r l) = (\lambda l)/\epsilon_0$
- Final Magnitude: $E = \lambda/(2\pi\epsilon_0 r)$
- Vector Form: $E = [\lambda/(2\pi\epsilon_0 r)]\hat{n}$
- Proportionality: The field falls off as $1/r$ (unlike a point charge which falls off as $1/r^2$).

Exam Trap: Caution! This formula assumes an infinitely long wire. It becomes invalid near the ends of a finite wire due to fringing effects where radial symmetry breaks down.



Check Your Understanding

If the perpendicular distance r from an infinitely long uniformly charged wire is doubled, what happens to the electric field intensity E ?

✓ [A: It is halved]

[B: It is quartered]

[C: It is doubled]

[D: It remains unchanged]

✓ **A: It is halved.**

The electric field due to a line charge is proportional to $1/r$. Doubling the distance cuts the field in half. Do not confuse this with a point charge, where $E \propto 1/r^2$ (which would quarter the field).



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