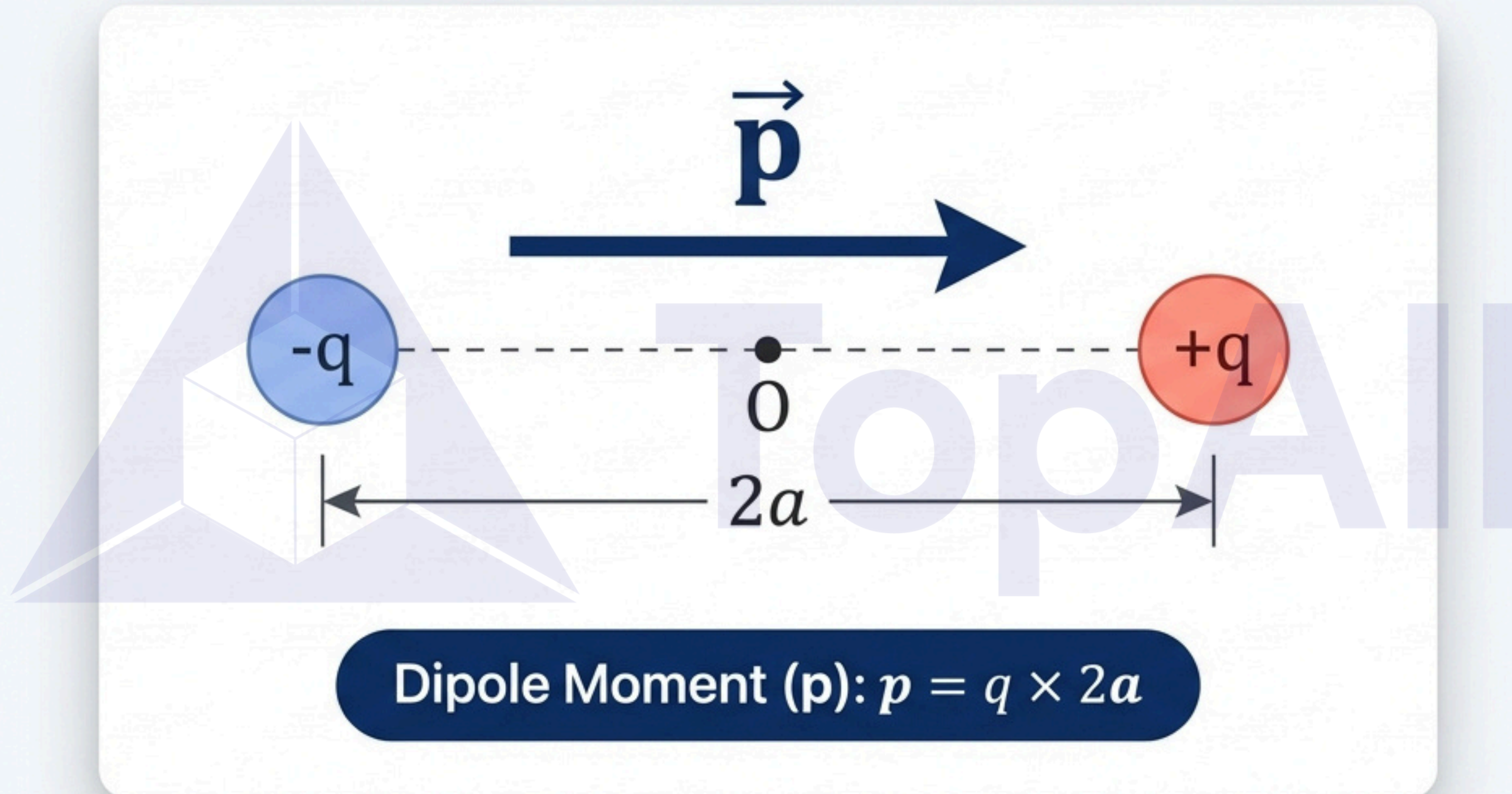


Field of an Electric Dipole

Electric dipole's field lines.
How a dipole's field behaves in
different regions.

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Exam Trap: Always remember, the dipole moment vector $\vec{p}$ points from negative to positive. This is the exact opposite of electric field lines!

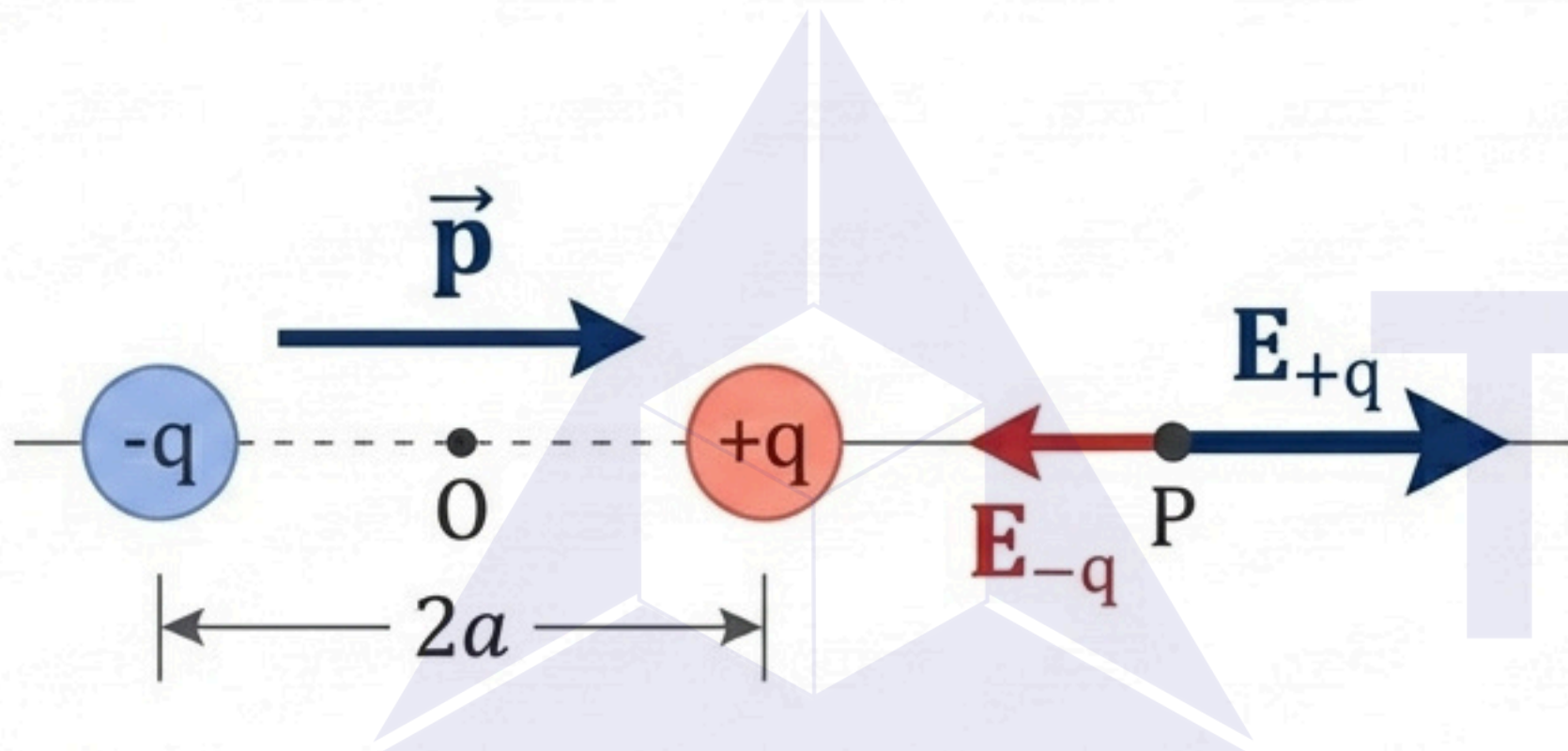
Axial Position Logic

The field at point P is the vector sum of fields from both charges.

Because P is physically closer to $+q$, the outward push (E_{+q}) overpowers the inward pull (E_{-q}).

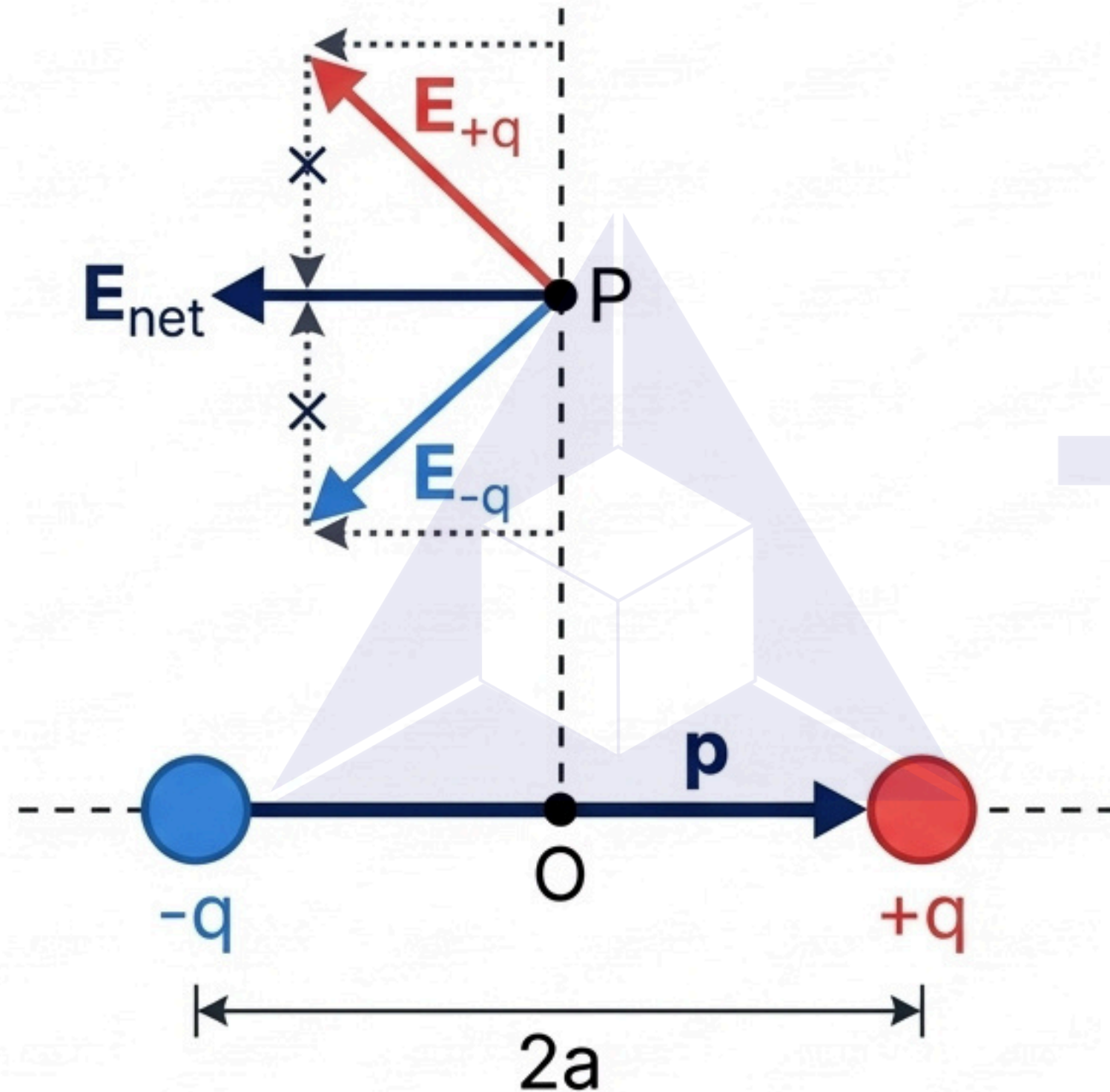
Key Takeaway

Net Field Direction: Parallel to the dipole moment vector ($\vec{p}$).



Equatorial Position Logic

Symmetry dictates the outcome. The vertical components normal to the axis perfectly cancel each other out. The horizontal components add up, parallel to the axis but moving left.



Key Takeaway

Net Field Direction: Anti-parallel (opposite) to the dipole moment vector ($-\mathbf{p}$).



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$$E=mc^2$$



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Axial Field (E_{ax})

$$E_{axial} = \frac{1}{4\pi\epsilon_0} \frac{2pr}{(r^2 - a^2)^2} \hat{\mathbf{p}}$$

Exact expression for any distance r .

Equatorial Field (E_{eq})

$$E_{equatorial} = -\frac{1}{4\pi\epsilon_0} \frac{\mathbf{p}}{(r^2 + a^2)^{3/2}} \hat{\mathbf{p}}$$

The negative sign mathematically confirms it points opposite to $\mathbf{p}$.

Legend Bar

[$\mathbf{p}$ = dipole moment]

[r = distance from center]

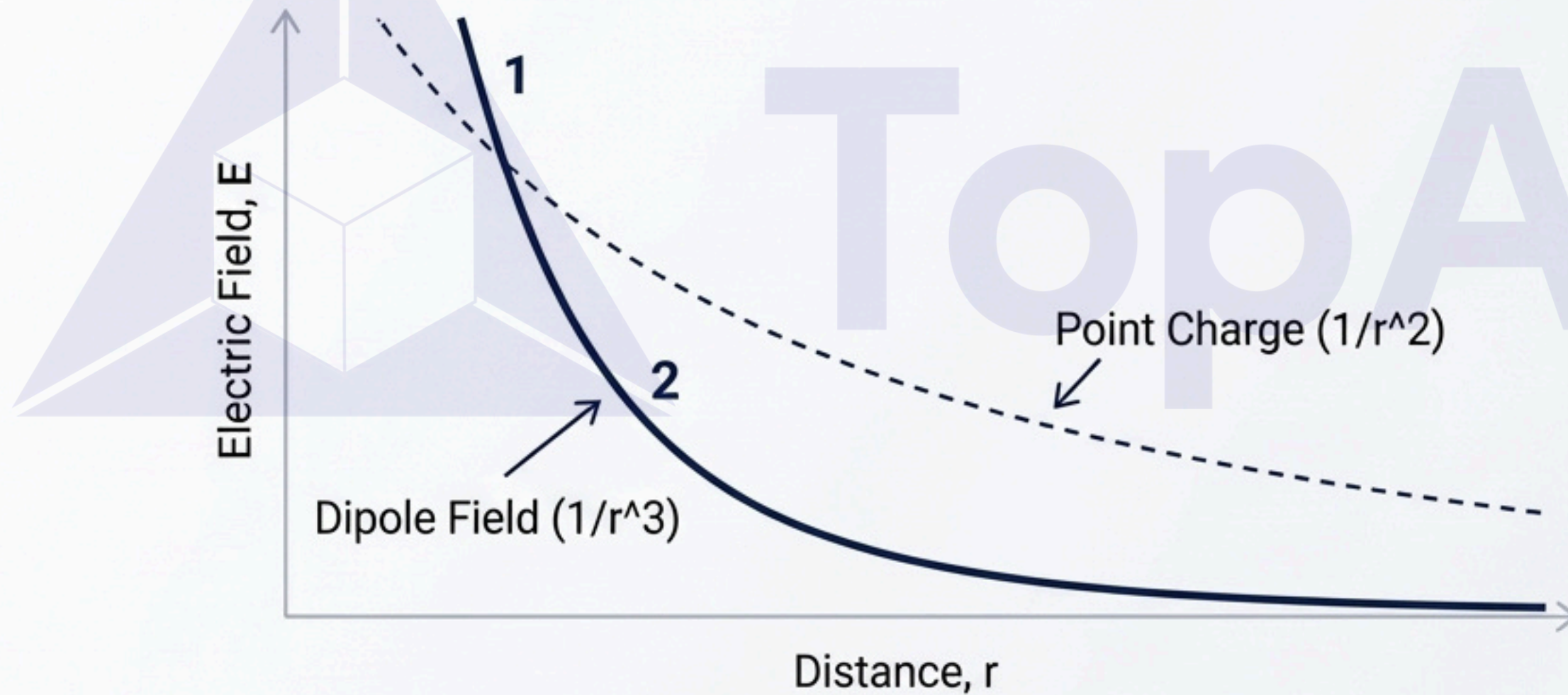
[$2a$ = charge separation]

The Far-Field Approximation ($r \gg a$)

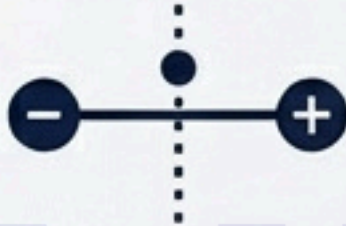
What happens when the distance r is **vastly greater than the dipole size a** ?
The complex formulas reduce dramatically.

Axial reduces to: $E \propto 2p/r^3$

Equatorial reduces to: $E \propto p/r^3$



Why does it fall faster? Because from a far distance, the fields of $+q$ and $-q$ nearly overlap and cancel each other out!

Feature	Axial Position	Equatorial Position
Position	On the axis 	On perpendicular bisector 
Direction	Parallel to p	Anti-parallel to p (opposite)
Short Dipole Formula	$\frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$	$\frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$

Pro-Tip: At the exact same distance r , the magnitude of the Axial field is always **exactly twice** the Equatorial field ($E_{\text{axial}} = 2E_{\text{eq}}$).

Far-field falls
as $1/r^3$

Axial = Parallel
direction

Equatorial =
Anti-parallel direction

Direction Check

If a dipole vector points exactly to the Right, which way does the equatorial field point?

Answer: Left

Magnitude Check

If E_{eq} at distance r is 10 N/C, what is E_{ax} at the same distance?

Answer: 20 N/C

Next Module: Dipole in a Uniform Field →



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