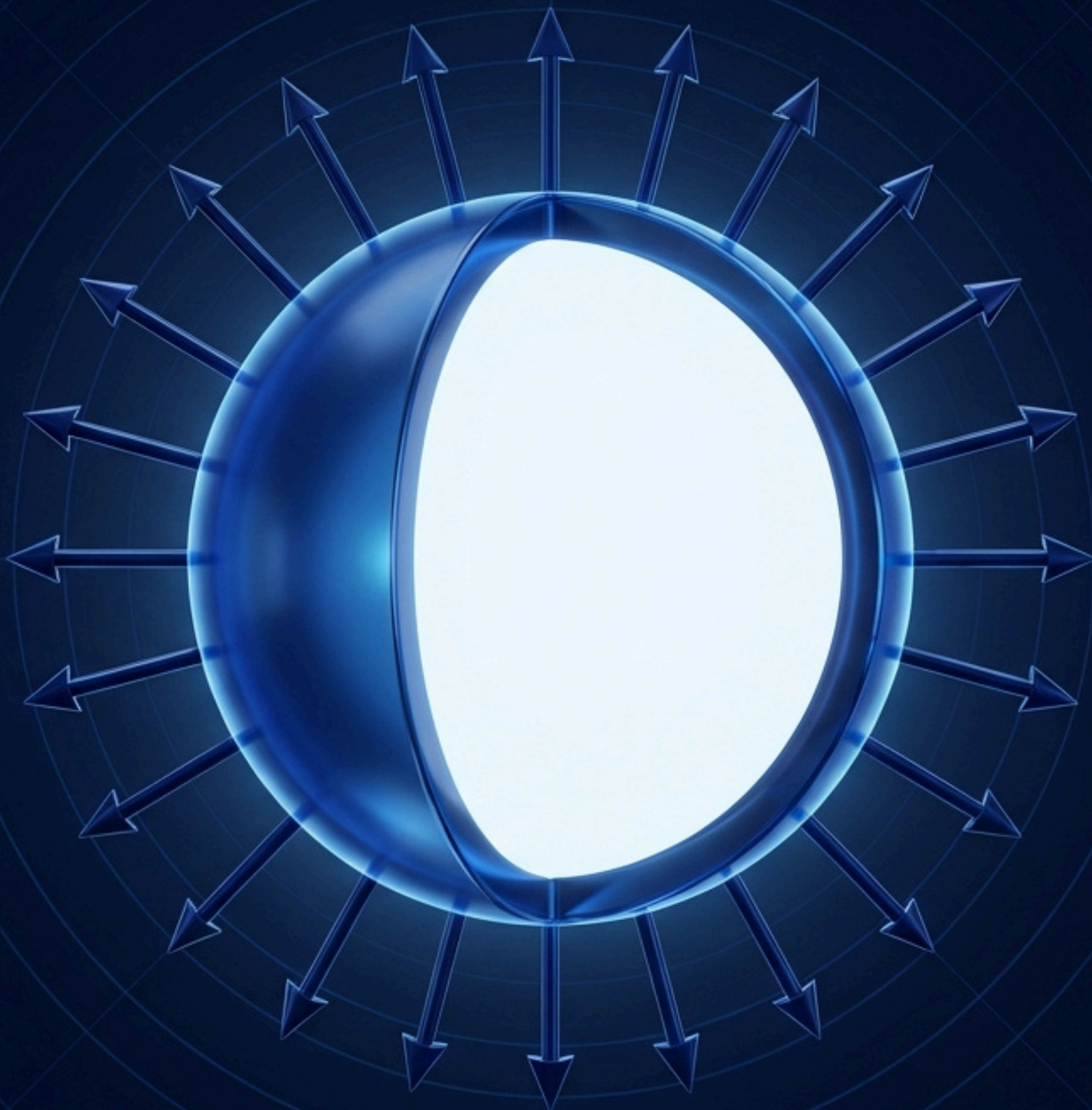


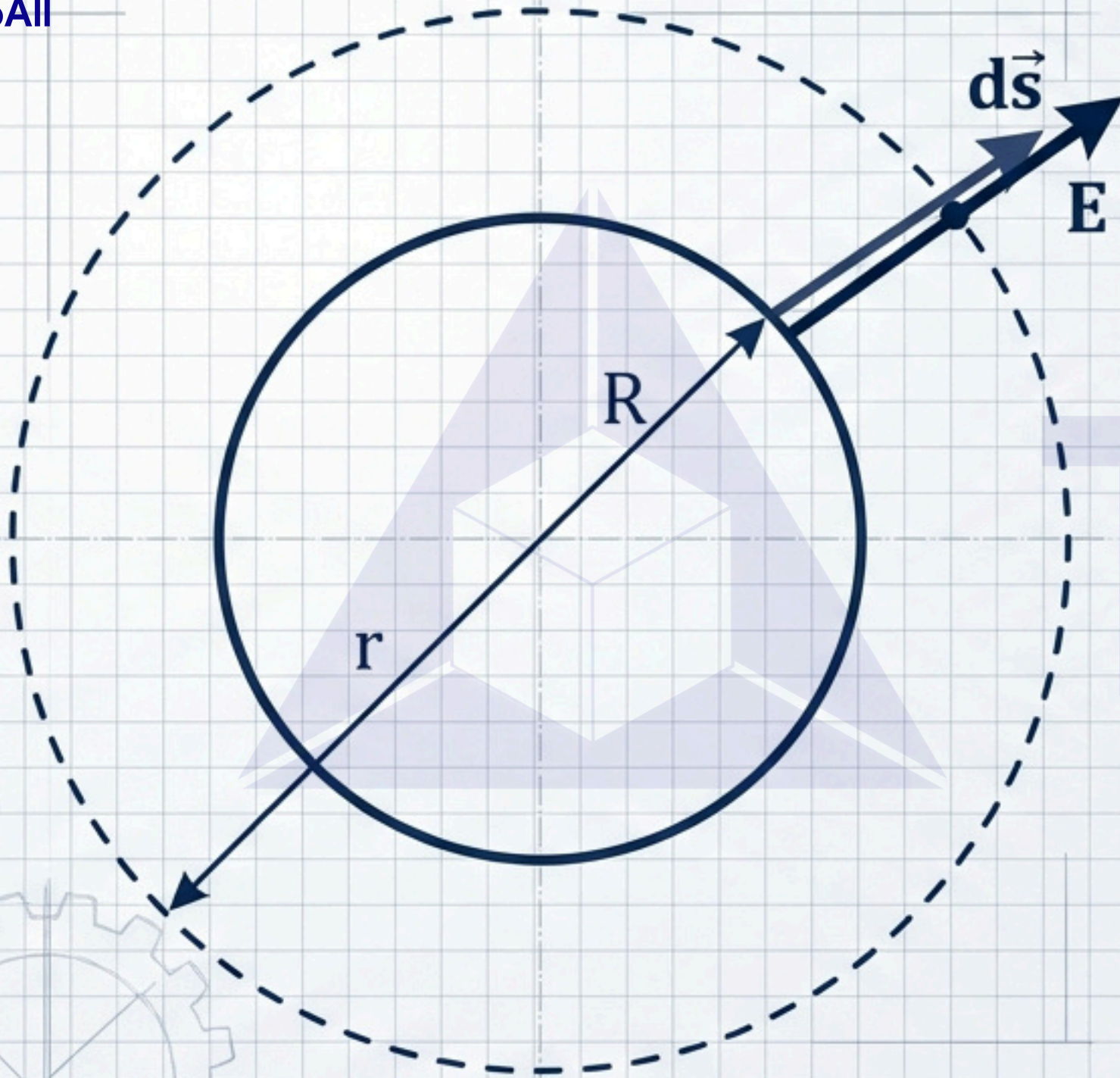
Electrostatics

Gauss's Law

# Electric Field due to a Thin Spherical Shell

Applying Gauss's Law to Uncover  
the Inside and Outside Reality





## The Core Enabler: Spherical Symmetry

Because all points on the spherical Gaussian surface are geometrically equivalent, the electric field magnitude  $E$  must be constant everywhere on that surface.

## Vector Alignment

Since the field is radial,  $\vec{E}$  is perfectly parallel to the outward normal area vector  $d\vec{s}$  ( $\theta = 0^\circ$ ).

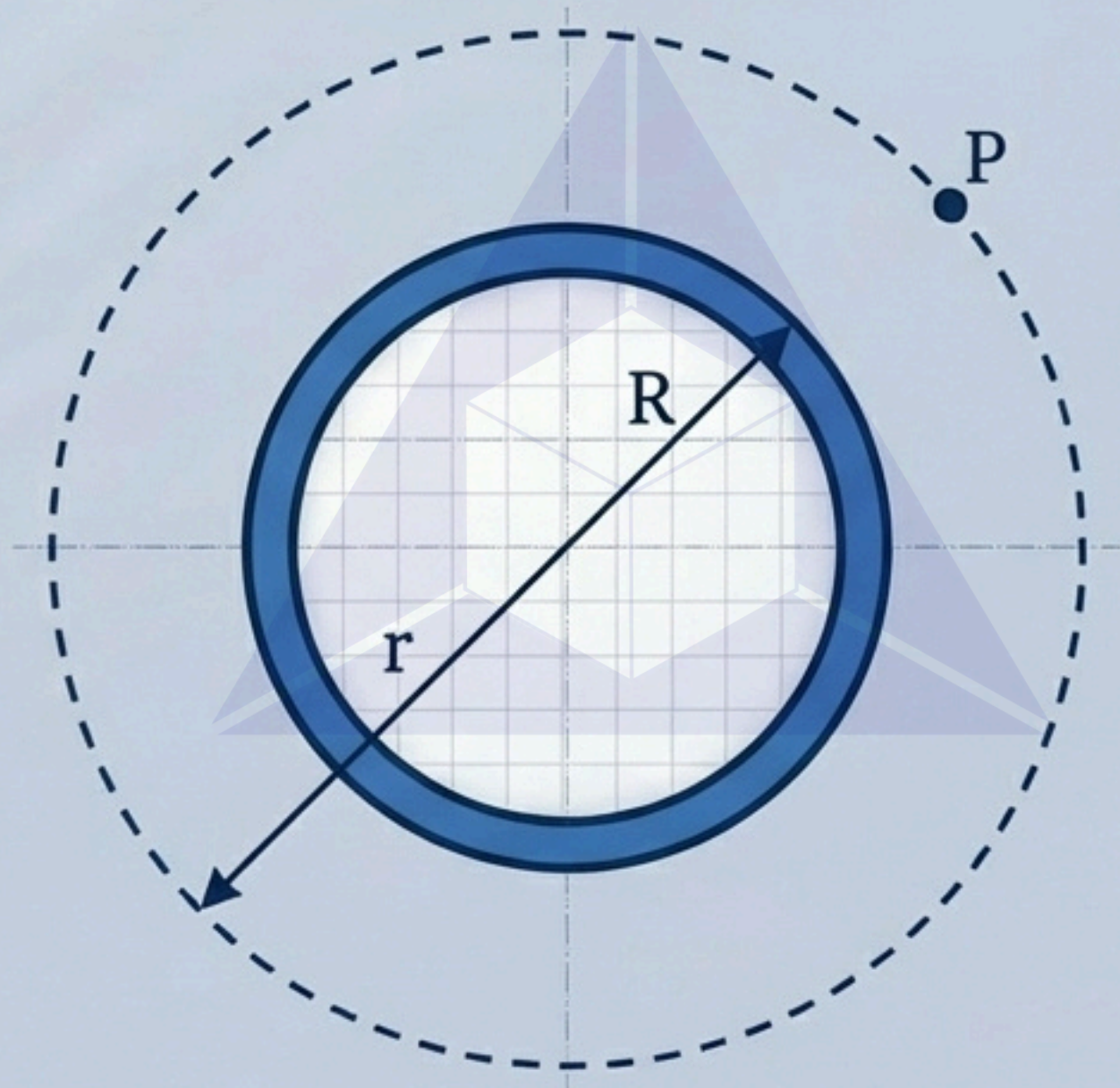
## Formula Panel

Therefore, the complex flux integral simplifies beautifully:

$$\oint \vec{E} \cdot d\vec{s} = E(4\pi r^2)$$

# Field Outside the Shell ( $r > R$ )

## Visual Setup



## Mathematical Derivation Flow

Step 1, Gauss's Law:  $E(4\pi r^2) = \frac{q}{\epsilon_0}$

Step 2: Solve for  $\vec{E}$ :  $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$

Step 3: Vector Form:  $\vec{E} = \frac{q}{4\pi\epsilon_0 r^2} \hat{r}$

In terms of surface charge density ( $\sigma$ ), since  $q = 4\pi R^2 \sigma$ , the field can also be written as  $\vec{E} = \frac{\sigma R^2}{\epsilon_0 r^2} \hat{r}$ .



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

$$E=mc^2$$



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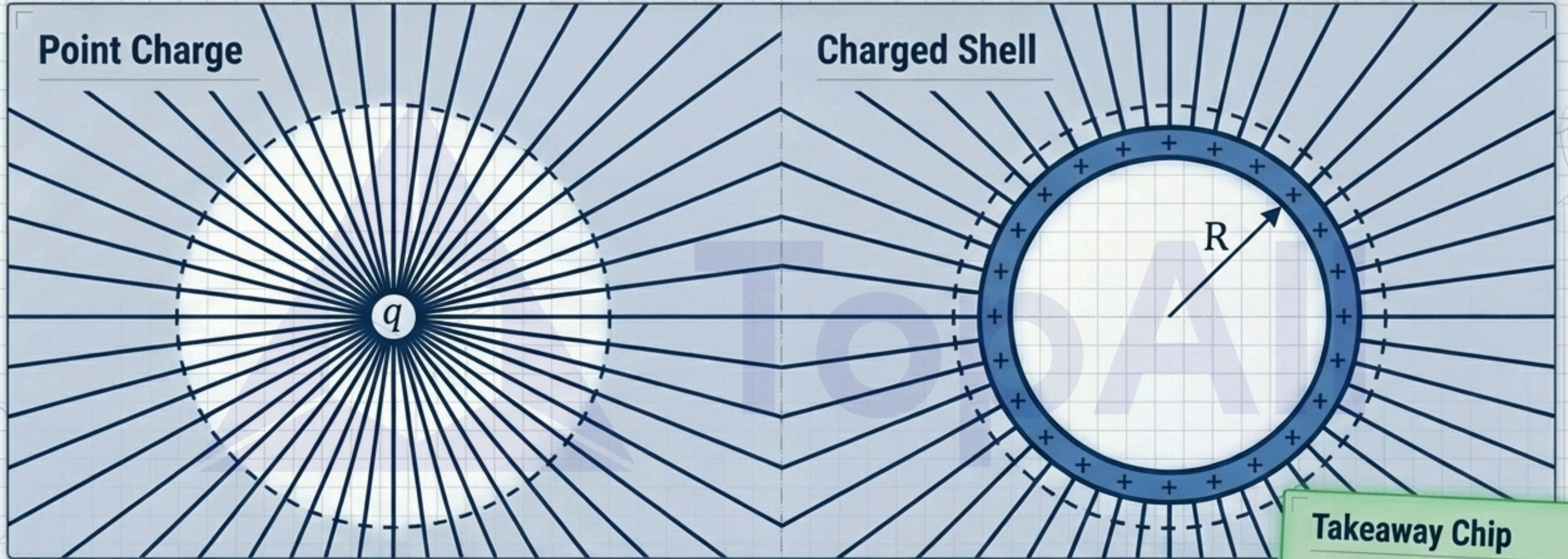
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# The Point Charge Illusion



## Insight Box

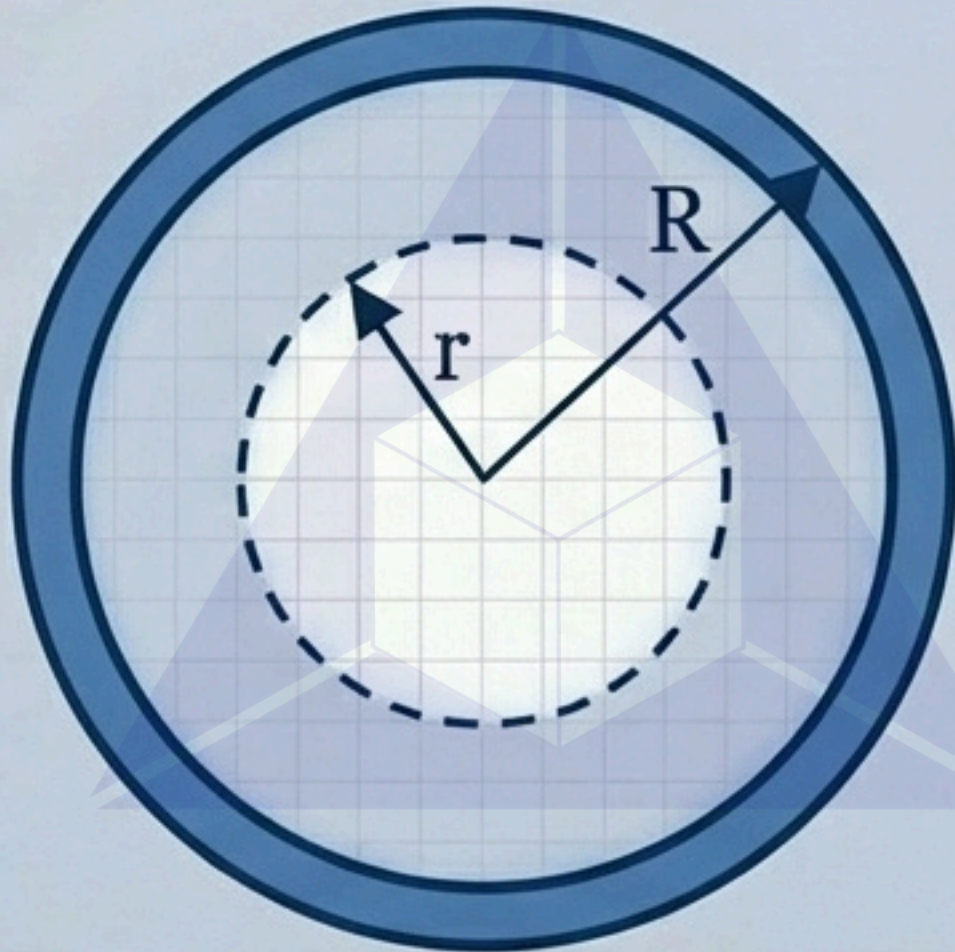
For any observer located outside the shell ( $r > R$ ), the shell behaves exactly as if its entire charge  $q$  were concentrated into a single point at its geometric center.

## Takeaway Chip

You cannot distinguish a charged shell from a point charge by only measuring the electric field from the outside.

# Field Inside the Shell ( $r < R$ )

## Visual Setup



## Mathematical Derivation Flow

Setup: Radius:  $r < R$

Crucial Fact:  $q_{\text{enclosed}} = 0$

Gauss's Law:  $E(4\pi r^2) = 0$

Result (**Bold**):  $\mathbf{E} = \mathbf{0}$

**CAUTION:** Do not use the volume charge density ( $\rho$ ) formula here! By definition, a thin shell is hollow. All charge resides exclusively on the outer surface.

# Why is the Inside Field Exactly Zero?

## Concept Block 1

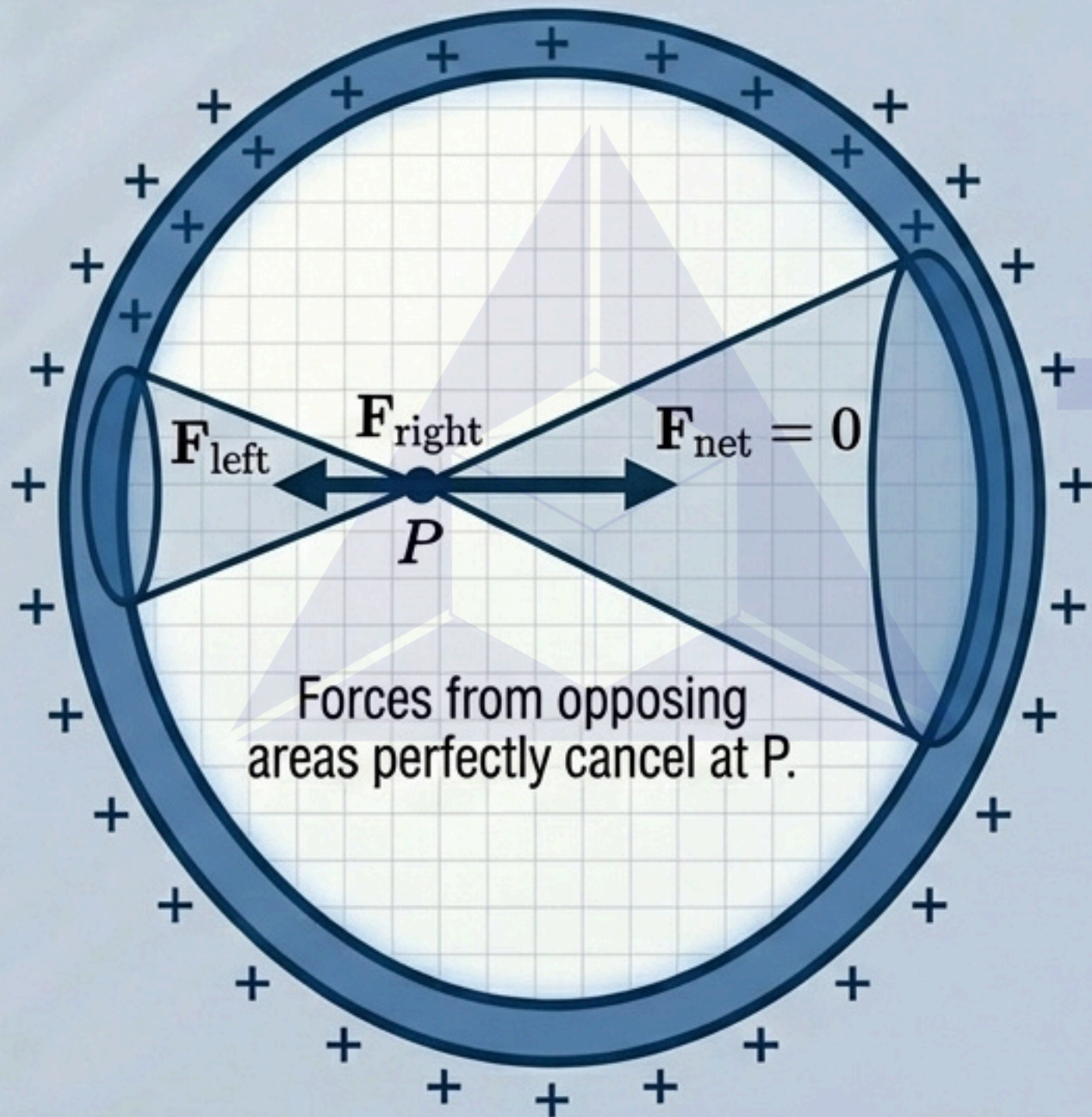
If you place a test charge inside the shell, it feels repulsive forces from all sides.

## Concept Block 2 (The Balancing Act)

Move closer to one wall, and the force from that wall increases (due to smaller distance). However, the opposing wall now exposes a much larger area of charge in your field of view.

## Concept Block 3 (Conclusion)

Because Coulomb's force drops precisely as  $1/r^2$ , the increased distance mathematically cancels the increased area. The net force is exactly zero everywhere inside.



# Synthesis & Practice



## Key Takeaways

| Region        | Condition  | Enclosed Charge ( $q_{in}$ ) | Electric Field (E)                             |
|---------------|------------|------------------------------|------------------------------------------------|
| Inside Shell  | $r < R$    | 0                            | 0                                              |
| Outside Shell | $r \geq R$ | $q$                          | $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$ |

## Practice Card

### CHECK YOUR UNDERSTANDING

A thin spherical shell of radius 10 cm carries a uniform charge of  $2\mu\text{C}$ . **What is the magnitude of the electric field** at a distance of 5 cm from the center?

## Solution

**0 N/C**

Since  $5\text{ cm} < 10\text{ cm}$ , the point lies inside the hollow shell where the field is universally zero.



# You've Learned the Theory.

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