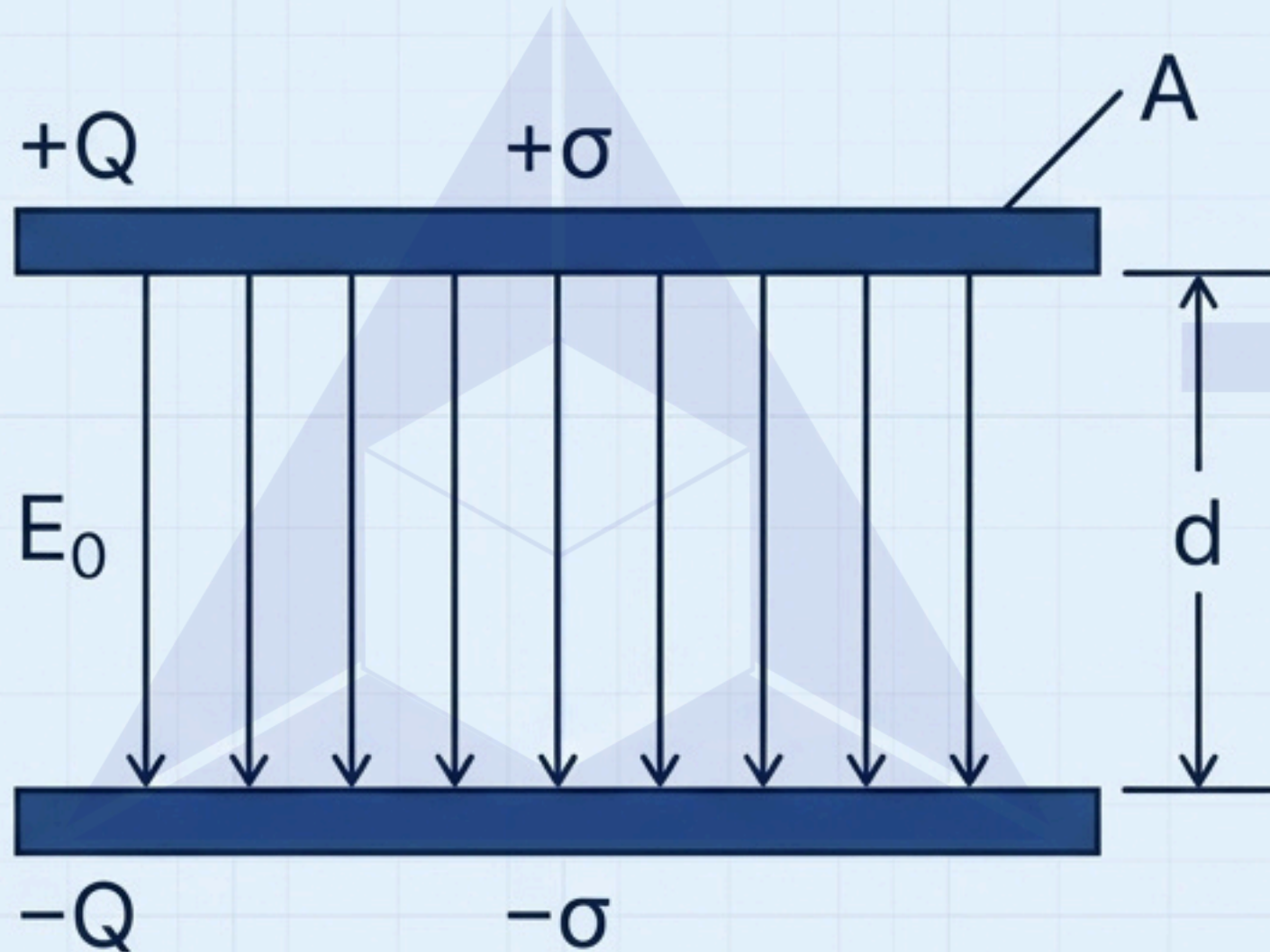


Insert a Dielectric, Increase the Capacitance

Discover exactly how insulating materials manipulate electric fields to supercharge a capacitor's ability to store energy.



The Baseline: Vacuum Capacitor



Vacuum Setup

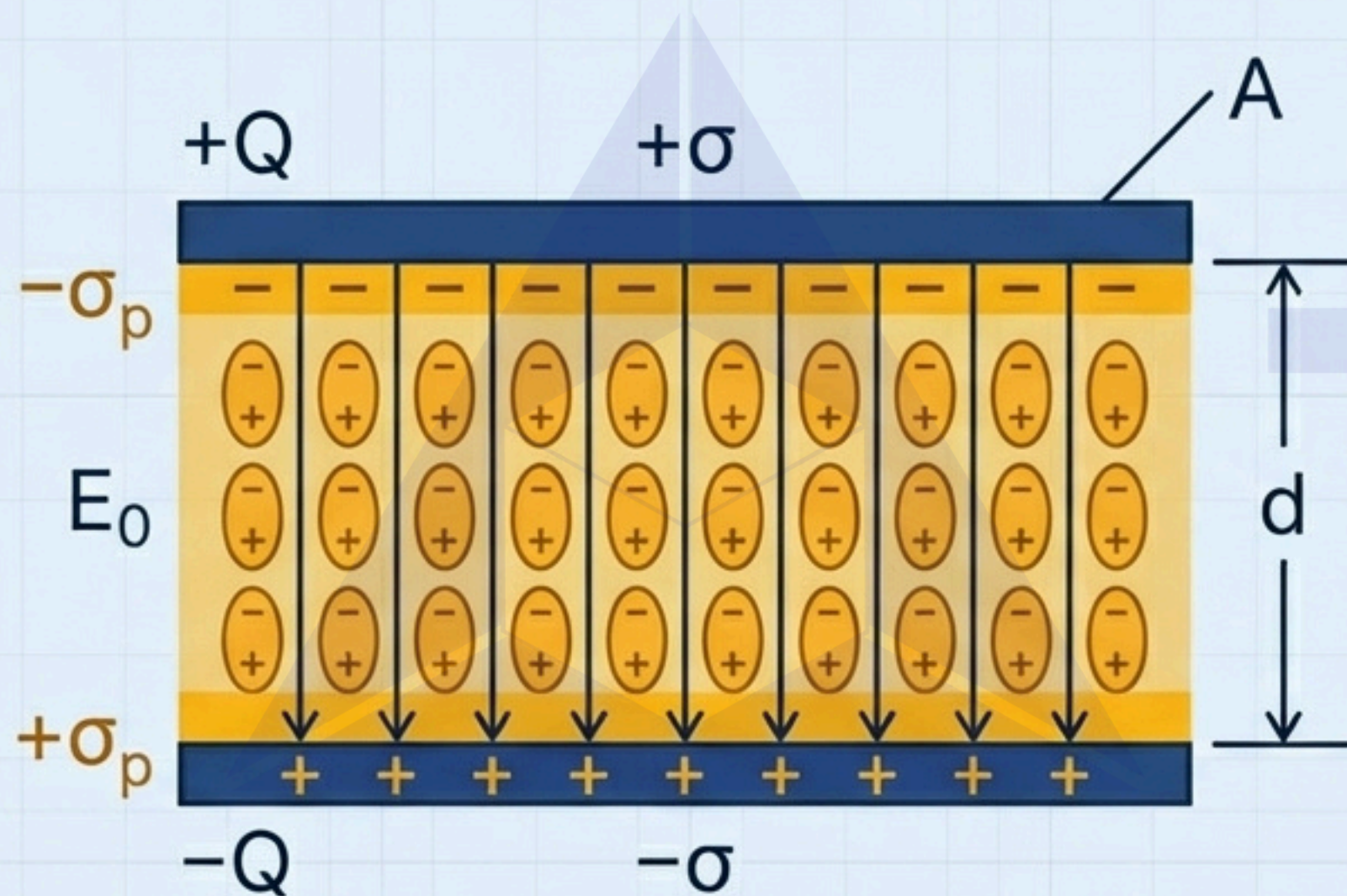
With only vacuum between the plates, the initial electric field E_0 and potential difference V_0 define our baseline capacitance C_0 .

$$E_0 = \frac{\sigma}{\epsilon_0}$$

$$V_0 = E_0 d$$

$$C_0 = \frac{Q}{V_0} = \frac{\epsilon_0 A}{d} \quad (\text{Eq. 2.46})$$

The Mechanism: Polarising the Dielectric



Induced Surface Charges

The external field E_0 stretches and re-orientes the molecules in the dielectric.

- Bulk interior remains neutral.
- Surfaces develop induced polarisation charges ($\pm\sigma_p$).
- These bound charges create their own opposing internal field.



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

$$E=mc^2$$



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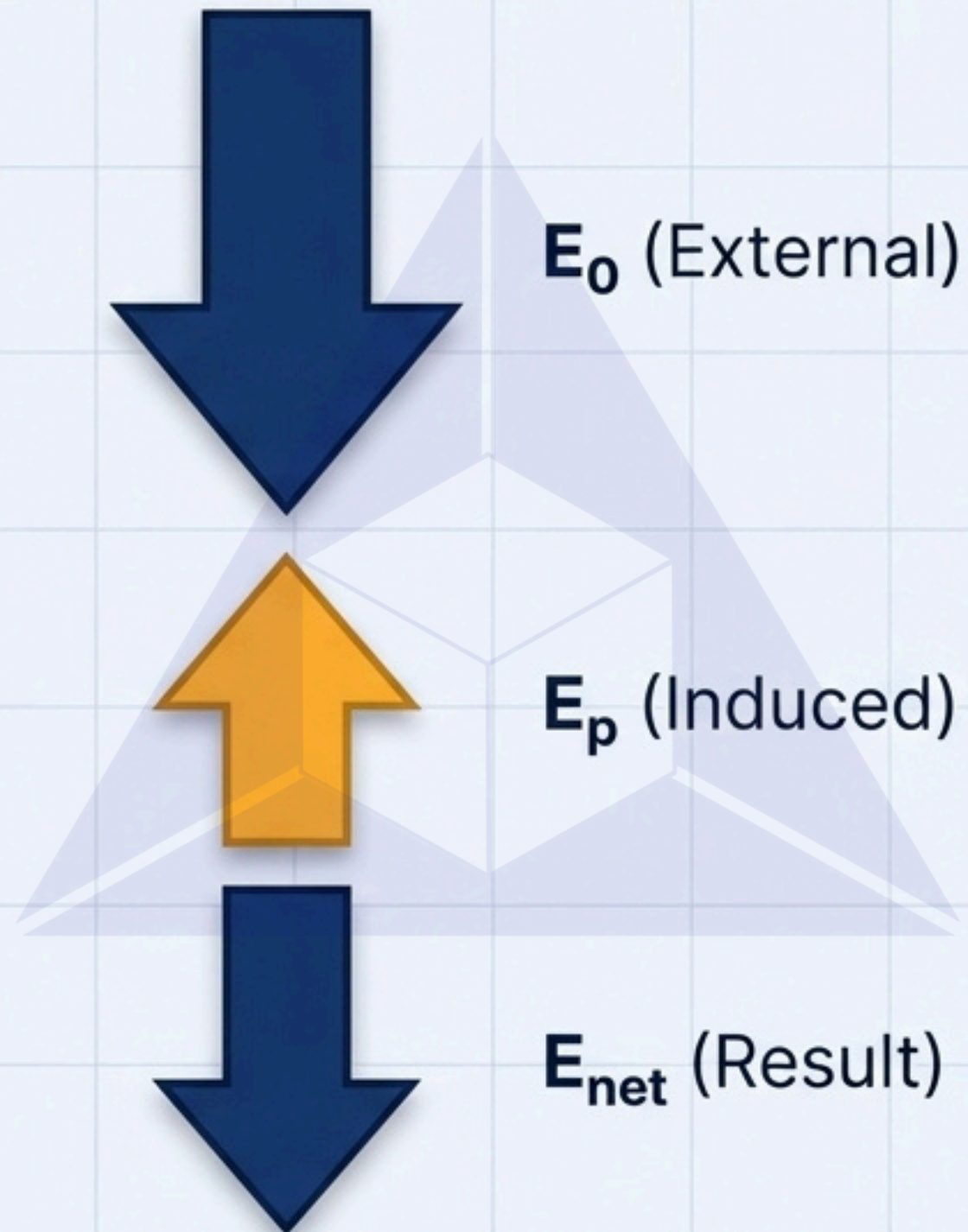
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Opposing Fields Reduce the Net Field



Net Surface Charge

The effective surface charge density becomes $\pm(\sigma - \sigma_p)$.

$$E = \frac{\sigma - \sigma_p}{\epsilon_0} \text{ (Eq. 2.47)}$$

The Dielectric Constant (K)

For linear dielectrics, the reduction is proportional to a constant $K > 1$.

$$\sigma - \sigma_p = \frac{\sigma}{K} \text{ (Eq. 2.49)}$$

Lower Field Means Lower Potential Drop

Step 1: The Potential Formula

Potential difference is just field times distance.

$$V = E \cdot d = \left[\frac{\sigma - \sigma_p}{\epsilon_0} \right] d$$

(Eq. 2.48)

Step 2: Substitute K

Replace the reduced charge density using our constant K.

$$V = \frac{\sigma d}{\epsilon_0 K}$$

Step 3: Expand to Q

Recall that surface charge density $\sigma = Q/A$.

$$V = \frac{Q d}{A \epsilon_0 K} \text{ (Eq. 2.50)}$$

The Result: Capacitance is Multiplied

Since $C = Q/V$, substituting our new lower V gives us:

$$C = \frac{\epsilon_0 \mathbf{K} A}{d} \quad (\text{Eq. 2.51})$$

$$C = \mathbf{K} C_0 \quad (\text{Eq. 2.54})$$

Where permittivity $\epsilon = \epsilon_0 \mathbf{K}$ (Eq. 2.52)

Because the dielectric constant $K > 1$, inserting a dielectric always increases the capacitance.

Key Takeaways & Exam Shortcuts



Exam Trap!

Remember, surface charge $\pm\sigma_p$ arises from bound charges in the dielectric, not free charges.

The free charge Q on the remains constant when the battery is disconnected.

The Isolated Capacitor Cheat Sheet

- **Maintains** constant Free Charge ($Q = Q_0$)
- **Induces** opposing polarisation field (E_p)
- **Reduces** net Electric Field ($E = E_0 / K$)
- **Drops** Potential Difference ($V = V_0 / K$)
- **Multiplies** Capacitance ($C = K \cdot C_0$)



You've Learned the Theory.

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