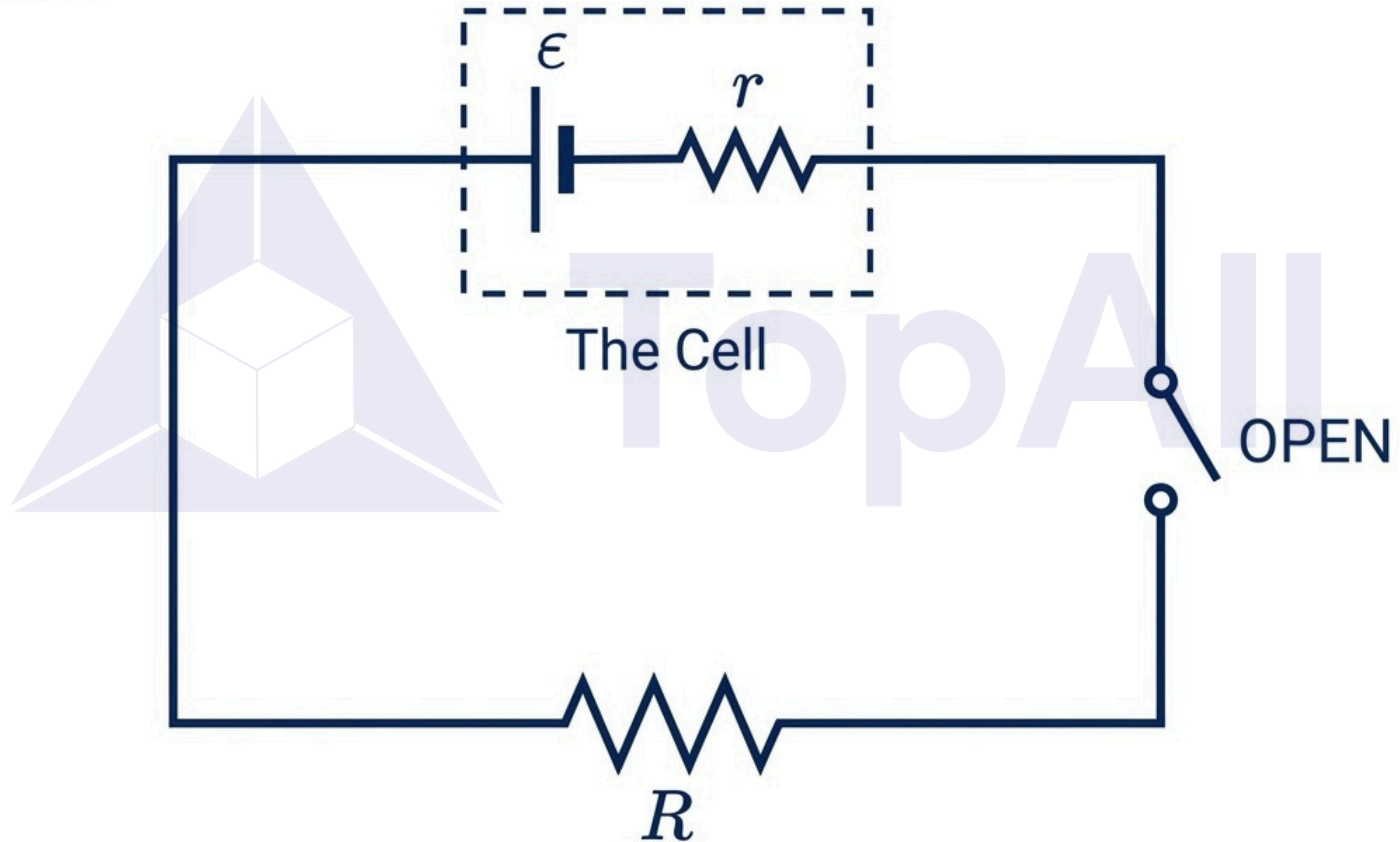


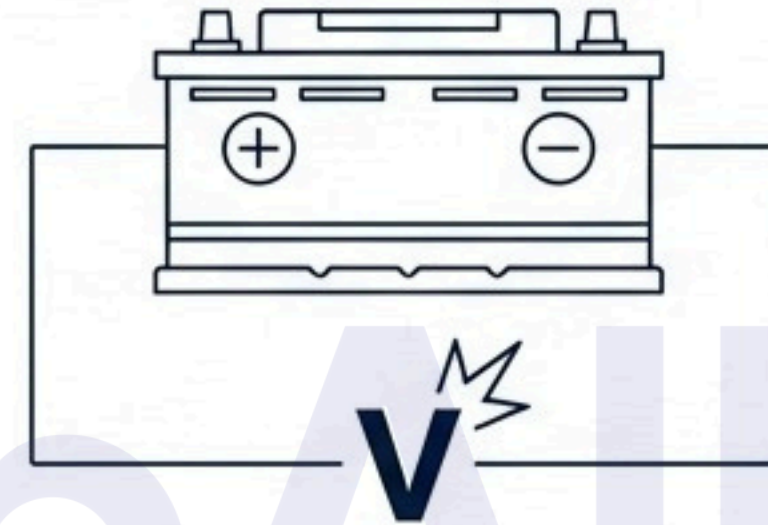
EMF, Terminal Voltage and Internal Resistance



The Misnomer of “Electromotive Force”

~~FORCE~~

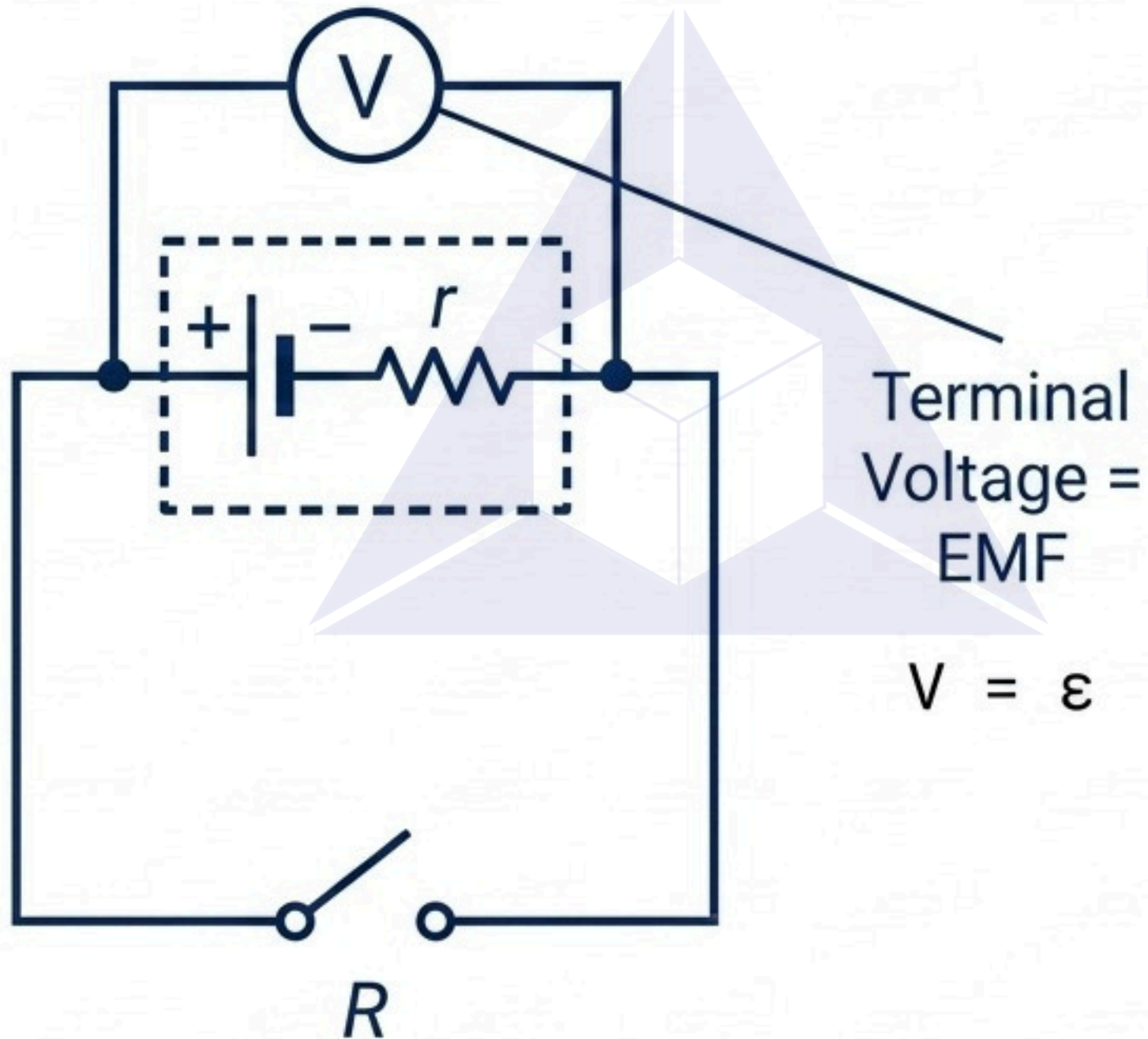
EMF sounds like a mechanical force measured in Newtons.



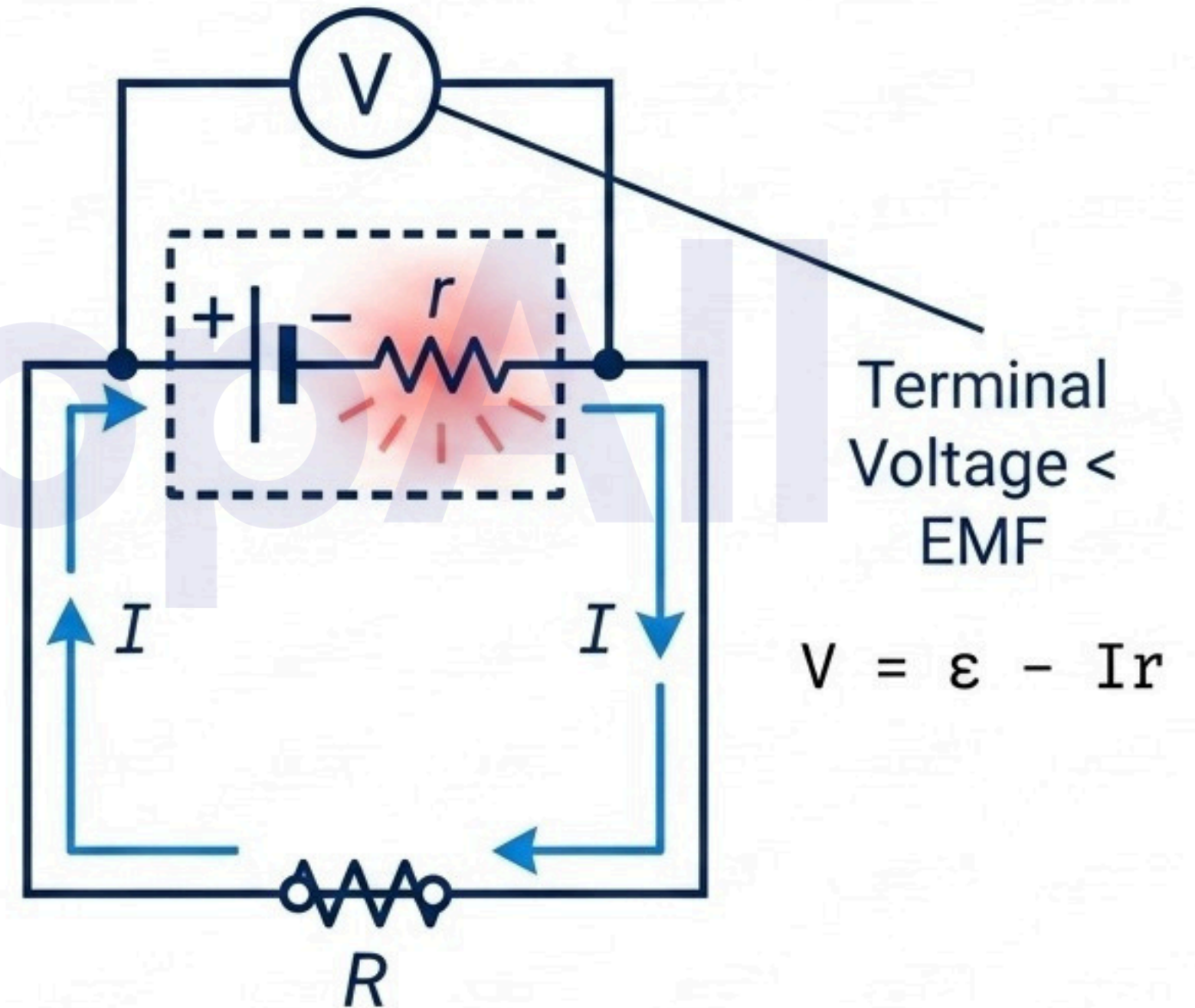
EMF ($\mathcal{E}$) is actually a Potential Difference (measured in Volts or Joules/Coulomb).
It represents the work done per unit charge by the source in taking the charge from lower to higher potential.

Circuit States: Open vs. Loaded Cell

Open Circuit ($I = 0$)



Loaded Circuit ($I > 0$)





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The Governing Equations

$$\epsilon = V_{+} + V_{-}$$

Total open-circuit potential difference between the electrodes

$$V = \epsilon - Ir$$

Terminal Voltage (Accounting for voltage drop inside the cell)

$$V = IR$$

Ohm's Law (Voltage drop across the external load)

$$I = \epsilon / (R + r)$$

Circuit Current (Equating $\epsilon - Ir$ and IR)

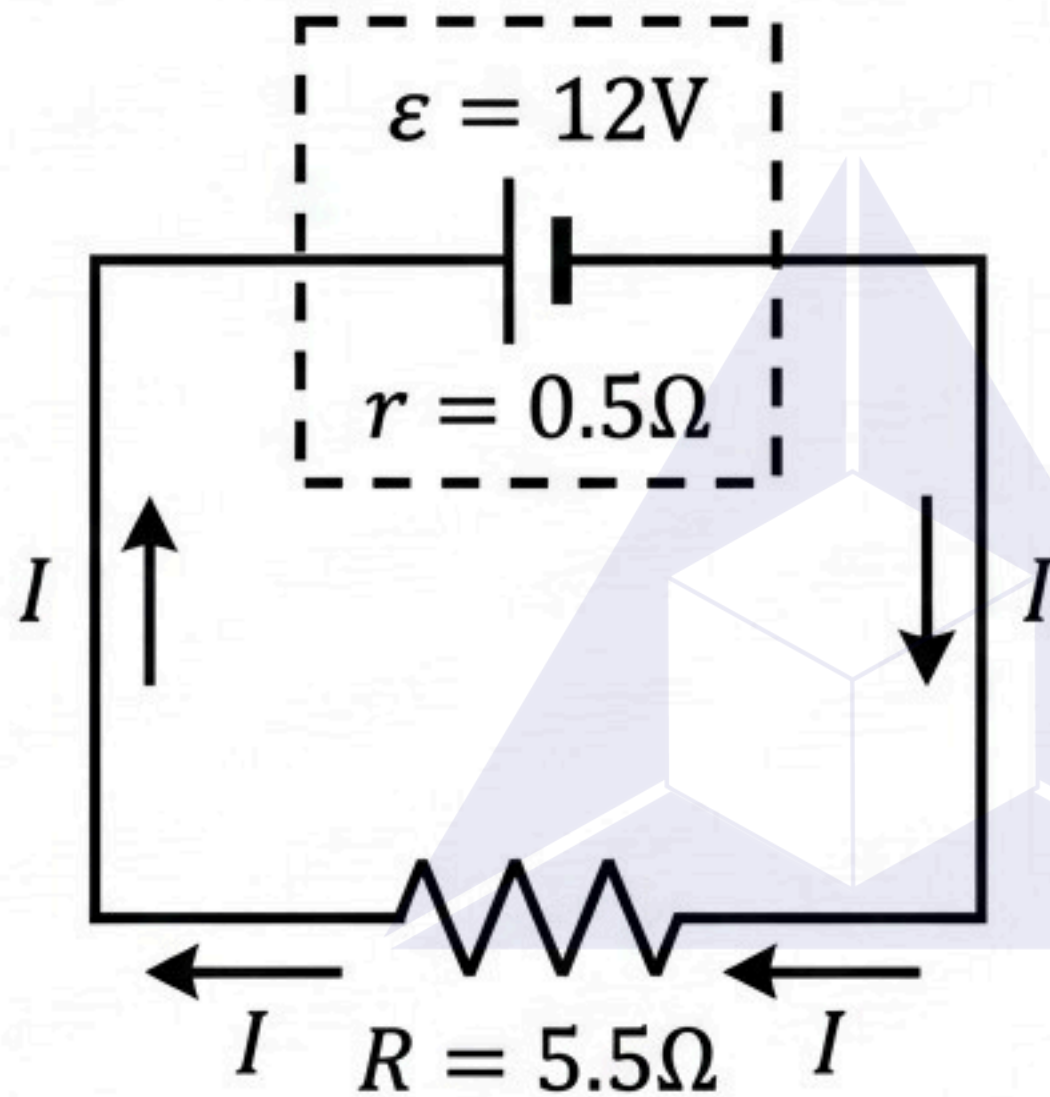


Assuming terminal voltage V always equals ε .

Terminal voltage only equals EMF when the circuit is entirely open ($I = 0$). As soon as current flows, the terminal voltage drops due to the cell's internal resistance ($V = \varepsilon - Ir$).

Short Circuit Trap: If external resistance $R = 0$, then $V = 0$.
The current hits its theoretical maximum: $I_{\max} = \frac{\varepsilon}{r}$

Mini Application



Find the steady current (I) and Terminal Voltage (V).

Step 1: Circuit Current

$$I = \varepsilon / (R + r)$$

$$I = 12 / (5.5 + 0.5) = 12 / 6$$

$$\mathbf{I = 2A}$$

Step 2: Terminal Voltage

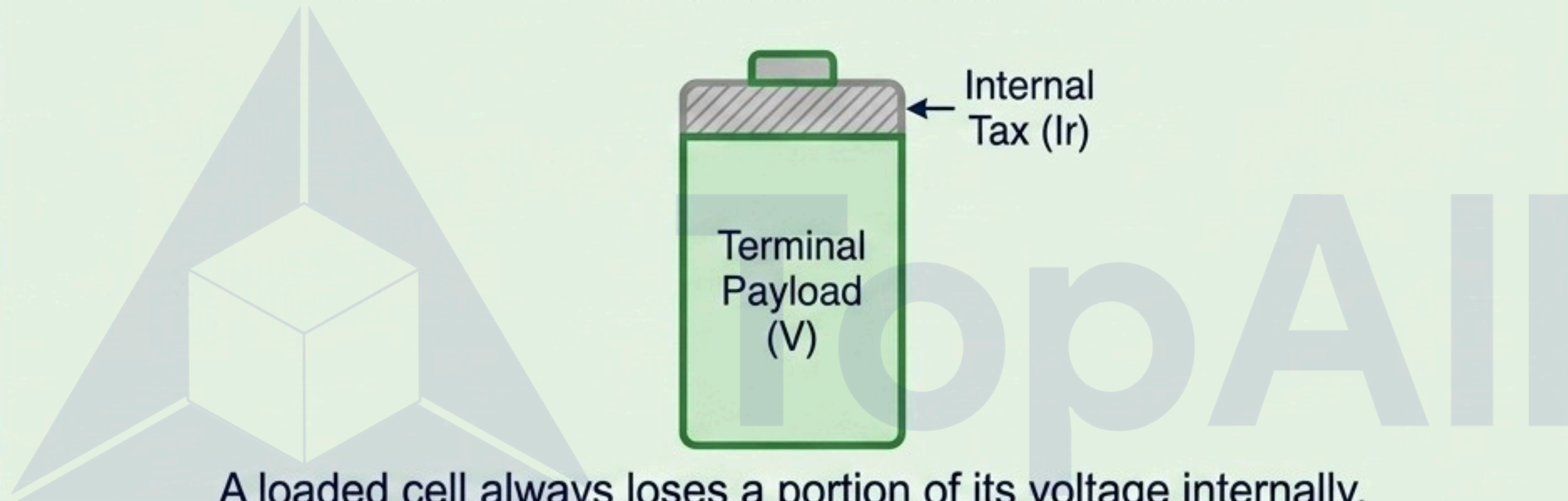
$$V = \varepsilon - Ir$$

$$V = 12 - (2)(0.5)$$

$$\mathbf{V = 11V}$$

Alternatively, checking with Ohm's Law: $V = IR = 2 * 5.5 = 11V$

The “Internal Tax” Rule.



A loaded cell always loses a portion of its voltage internally.

Think of EMF (ϵ) as the gross voltage generated by the battery.
The internal electrolyte extracts a mandatory “tax” (Ir) just to move the charge through the cell itself.

The external circuit only receives what is left: the net Terminal Voltage (V).

$$V = \epsilon - Ir$$



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