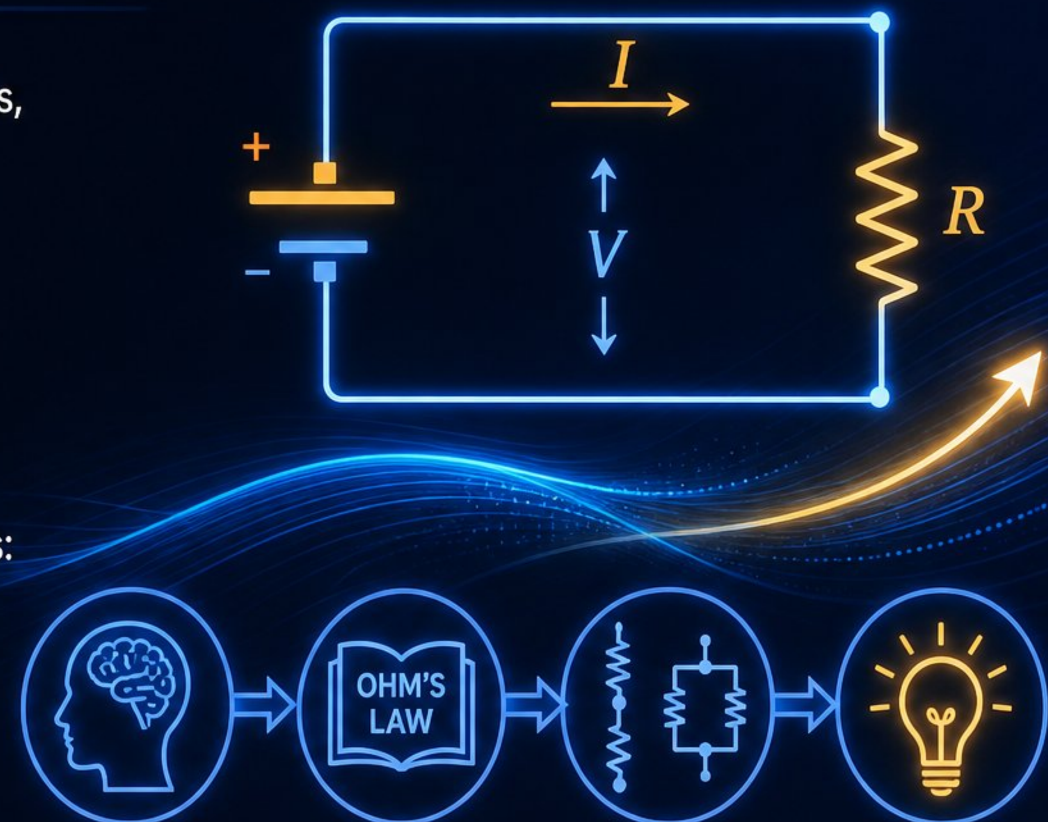
Introduction to
Electric Circuits:
Current, Voltage, and Resistance

- Build accurate conceptual models for circuits, not just memorize formulas
- Current, voltage, and resistance are the foundation of all circuit analysis
- Journey from mental models through Ohm's Law to series/parallel patterns
- Directly confronting common misconceptions: 'constant current' and 'current consumption'
- Adopting a scientific model means letting go of intuitive but incorrect ideas

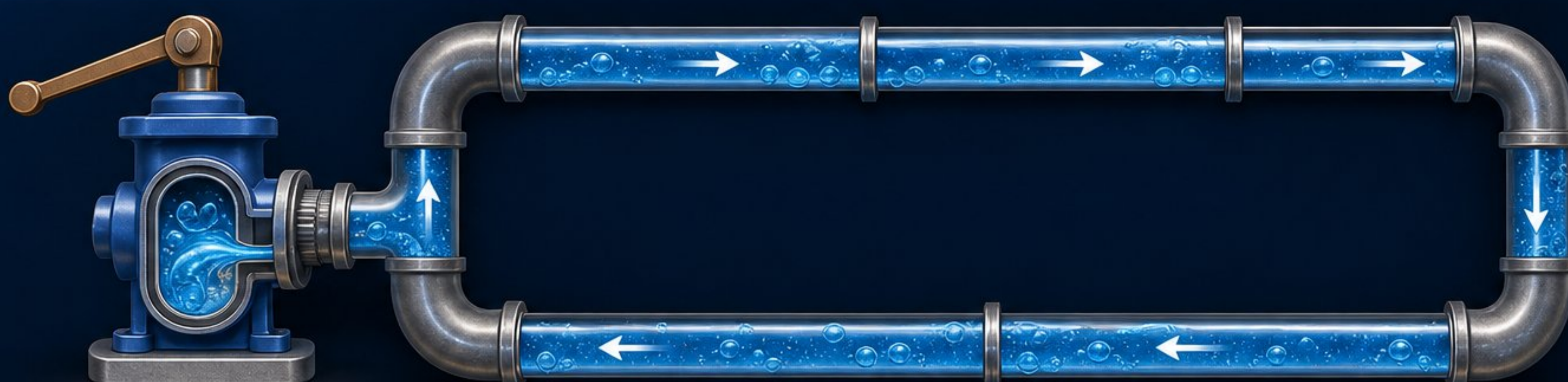


Confronting the Misconceptions We Bring

- Battery is not a source of constant current
- Charge is never 'used up' by components
- Voltage and current are distinct concepts
- Adopt the cyclic simultaneous model for circuits
- Let go of ideas that don't hold up to evidence

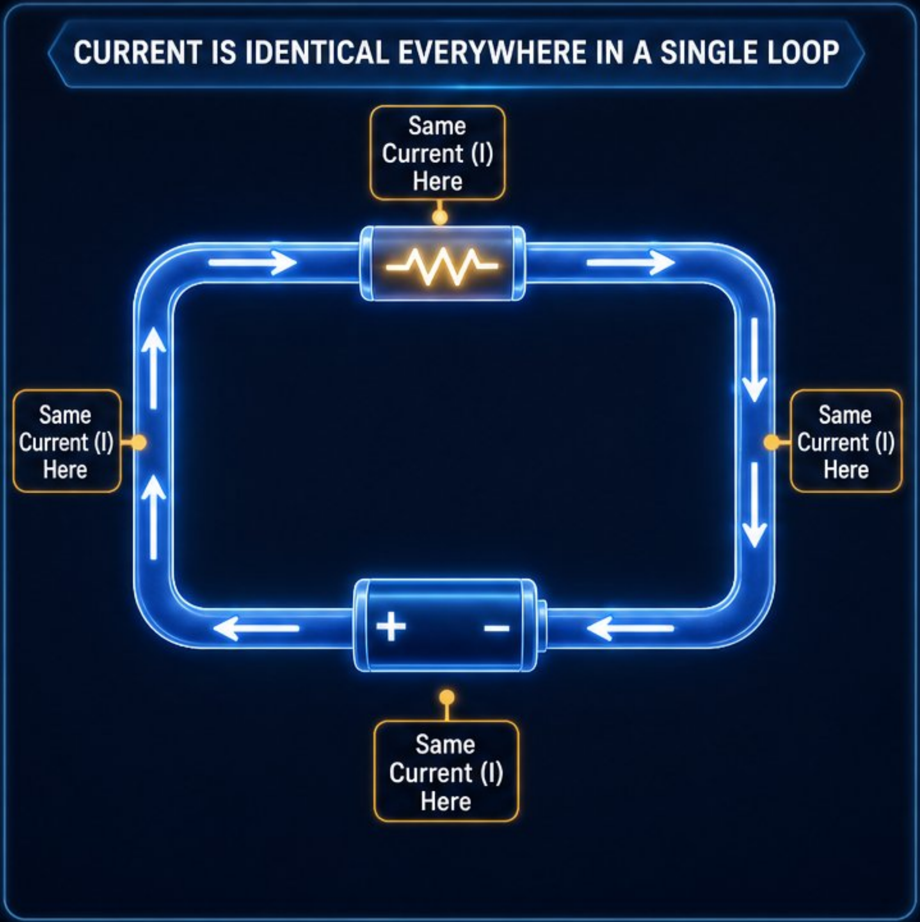
The Non-Negotiable: What a Circuit Absolutely Needs

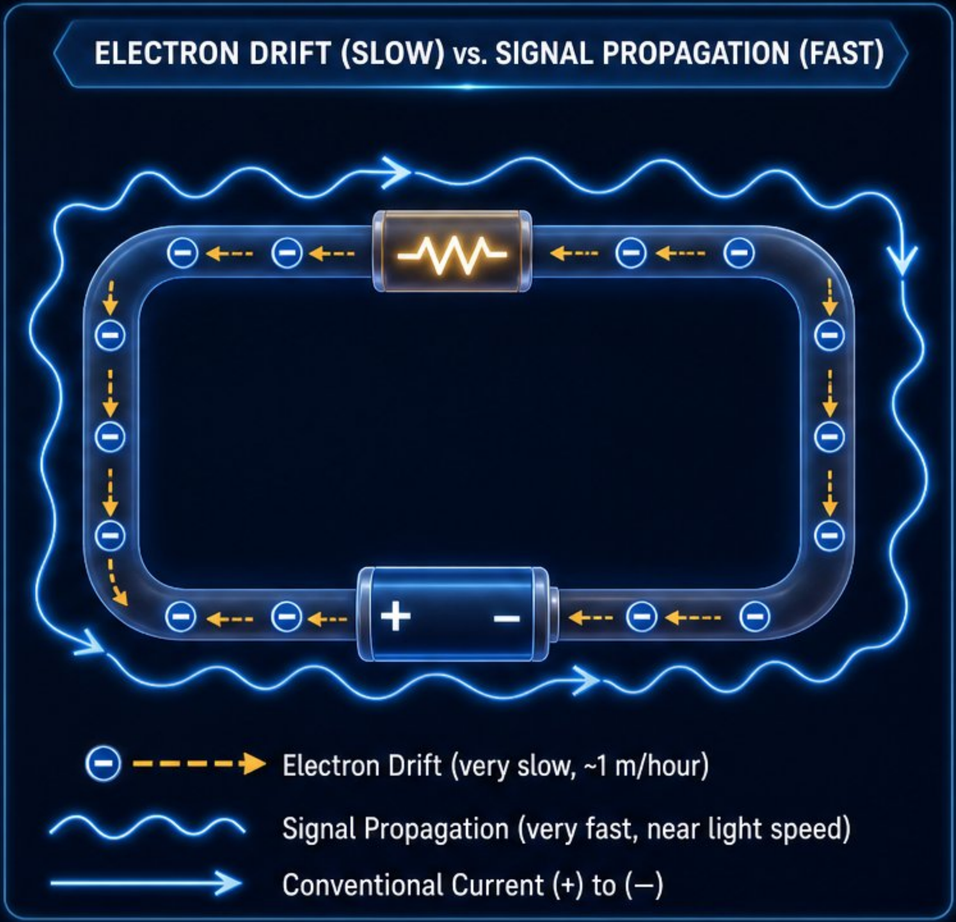
- A closed, continuous conducting loop is required for charge to flow
- Switches open/close the loop; conductors vs. insulators matter
- Circuit as a completely filled, continuous chain or hose loop
- Battery is an energy pump, not a source of fresh charge



Electric Current: It's Not Consumed, It's a Cycle

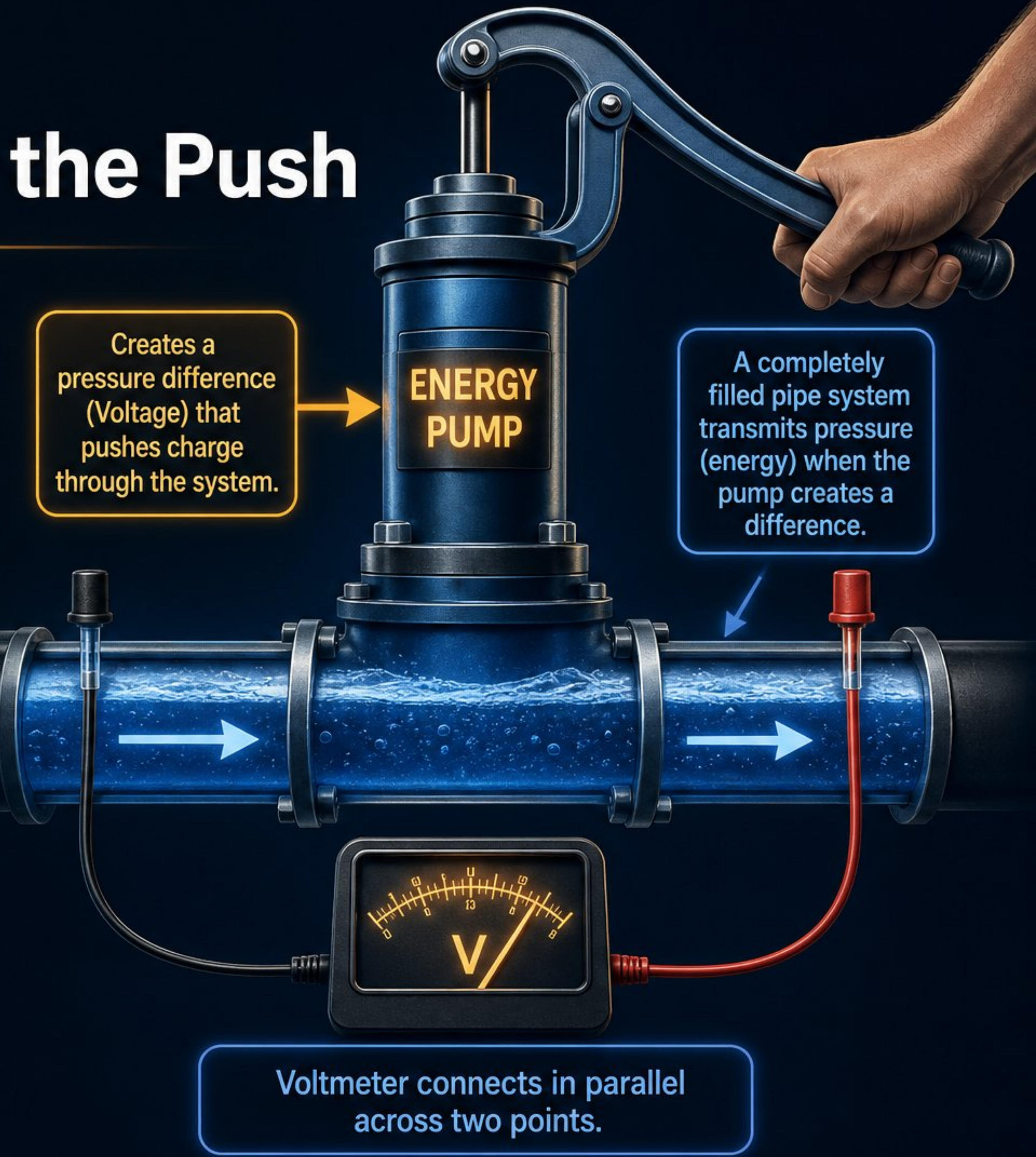
- Current (I) = charge flow rate past a point, measured in amperes (A); 1 A = 1 C/s
- Conventional current flows (+) to (−); free electrons drift the opposite way
- Electron drift speed (~1 m/hour) vs. near-light-speed signal propagation
- Charge carriers are never "used up"; current is identical everywhere in a single loop





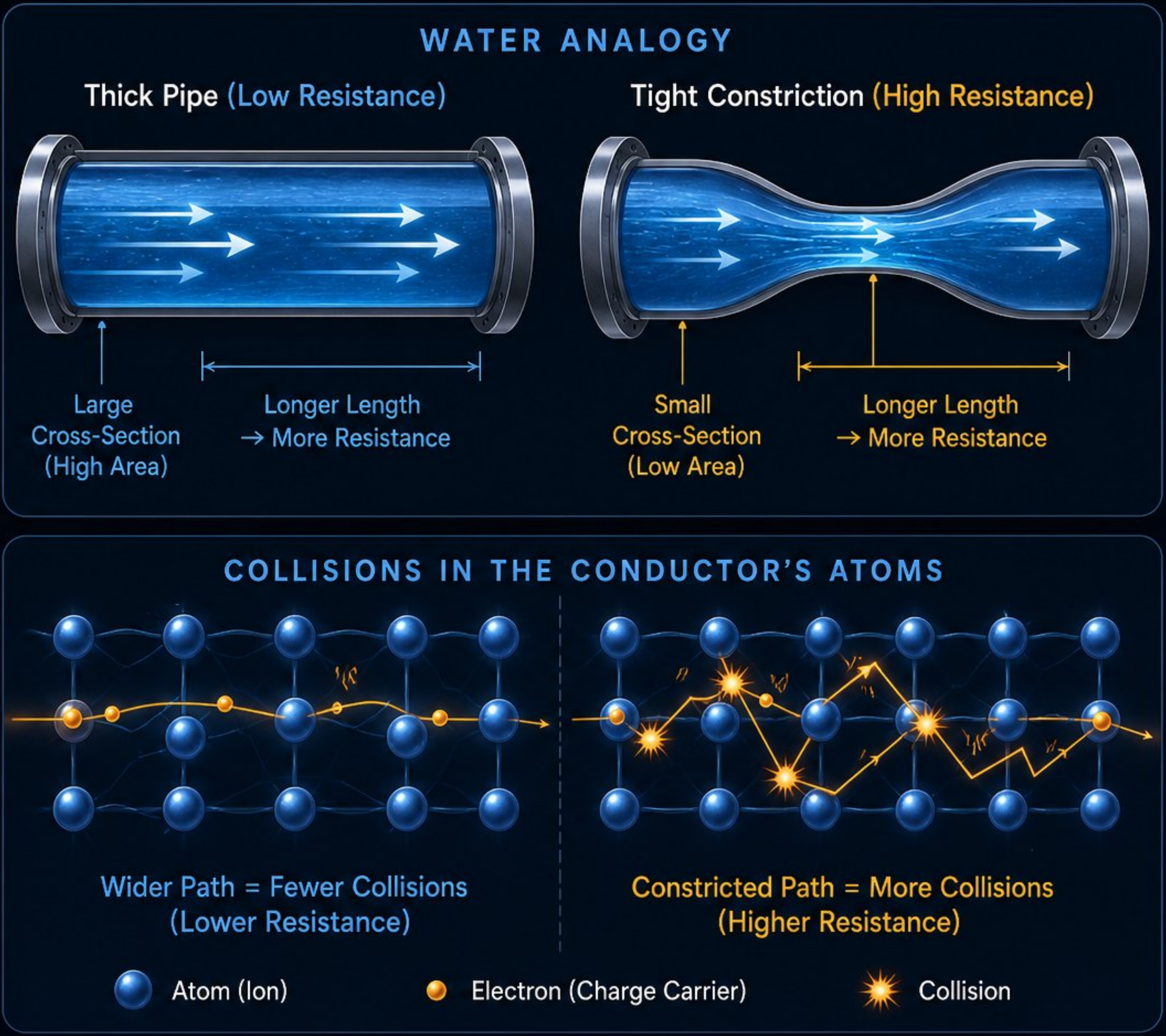
Voltage:
The Reason for the Push

- **Voltage (V)** is an electric pressure difference that causes charge to flow, measured in volts across two points.
- The battery acts as an **'energy pump'** creating a pressure difference in a completely filled pipe system.
- **EMF** is the pump's ideal pressure; **terminal voltage** is the actual pressure available under load.
- Everyday levels: 1.5V (AA cell), 9V (rectangular battery), 120/230V mains. **Voltmeters connect in parallel.**



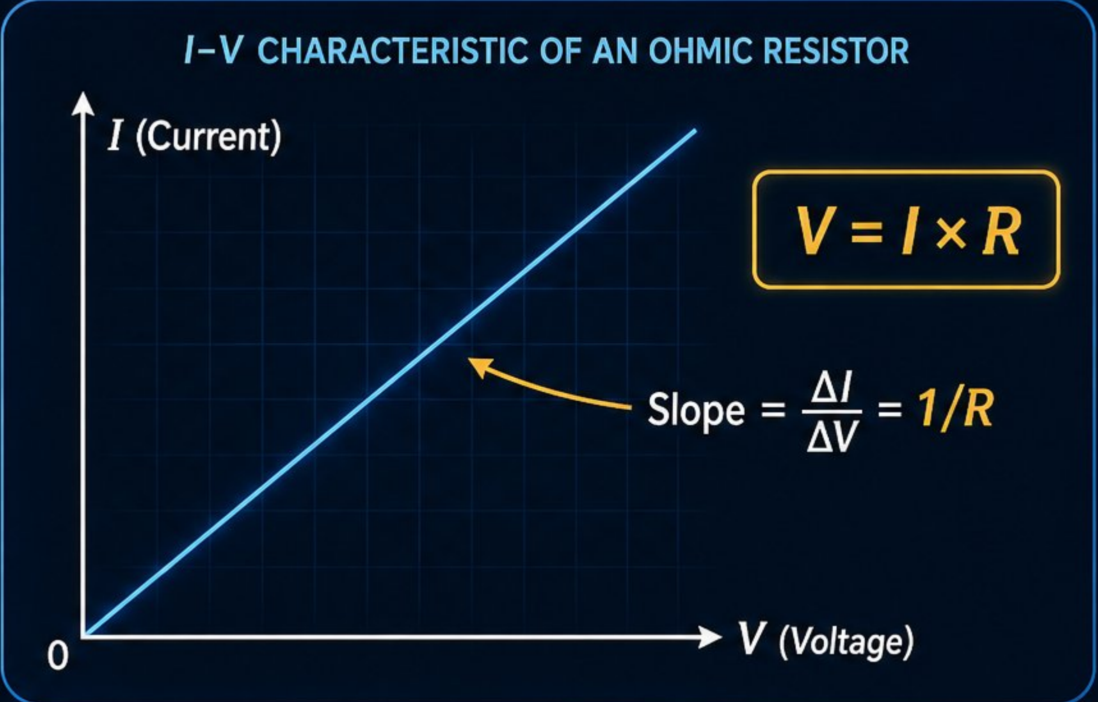
Resistance: The Opposition to Flow

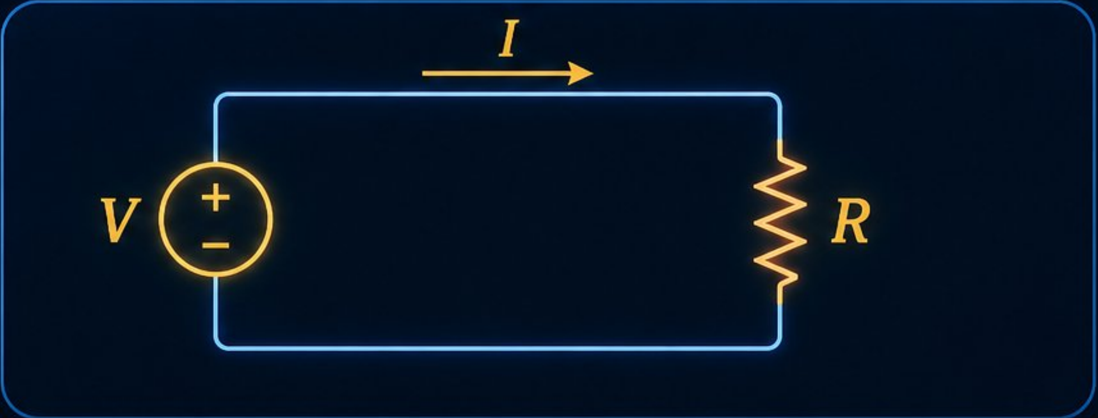
- - Resistance (R) limits current; arises from collisions in the conductor's atoms
- - Longer = more R; thinner = more R; depends on material resistivity
- - Water analogy: thick pipe vs. tight constriction = resistor
- - Everyday scale: wire ~ few Ω, insulation ~ MΩ



Ohm's Law:
The Unifying Relationship

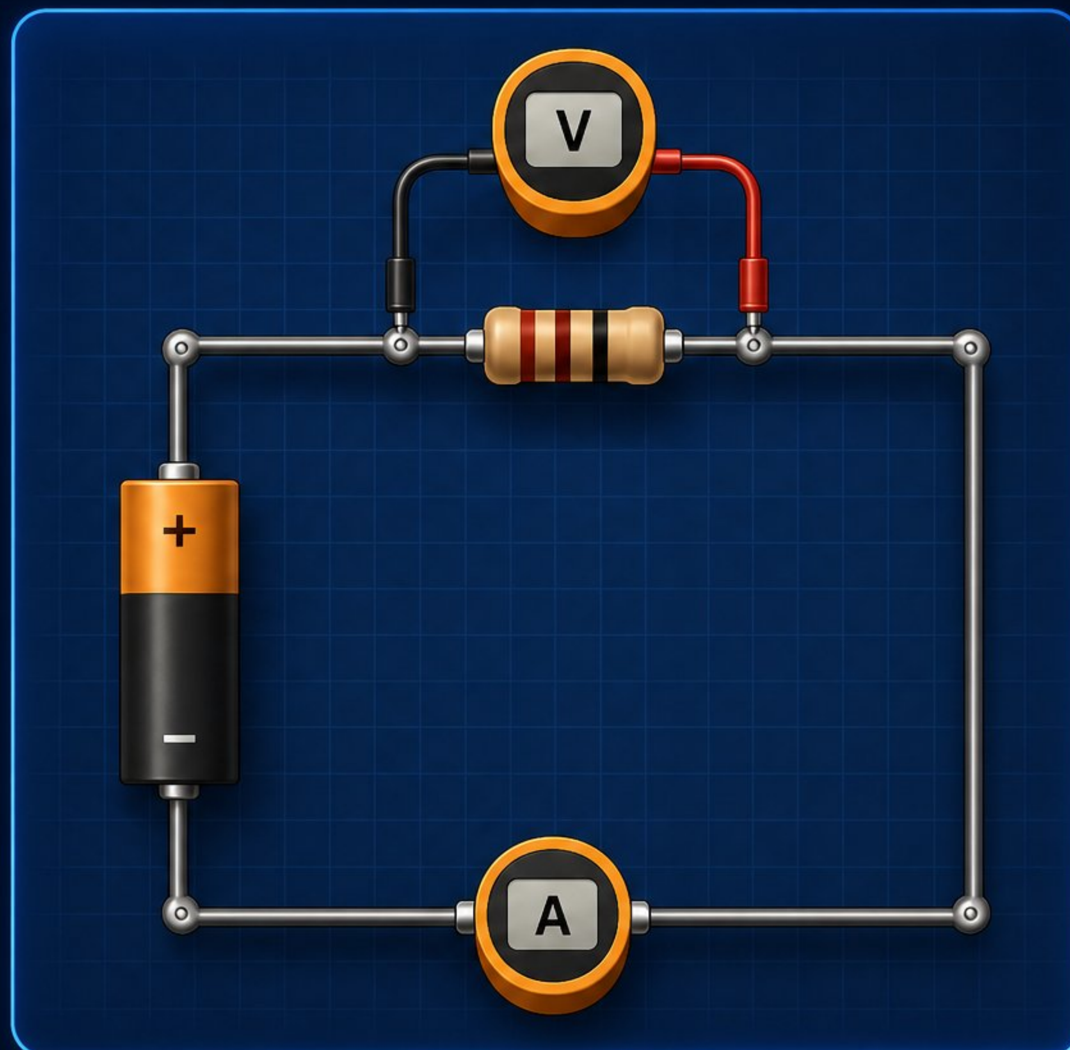
- The quantitative link: $V = I \times R$ (Current = Voltage / Resistance).
- Current is directly proportional to voltage; double V, I doubles.
- Current is inversely proportional to resistance; halve R, I doubles.
- *I*-V graphs for ohmic resistors form a straight line; slope is 1/R.
- Worked example: A 120V supply powers a 192Ω lamp -> I = 0.625 A.





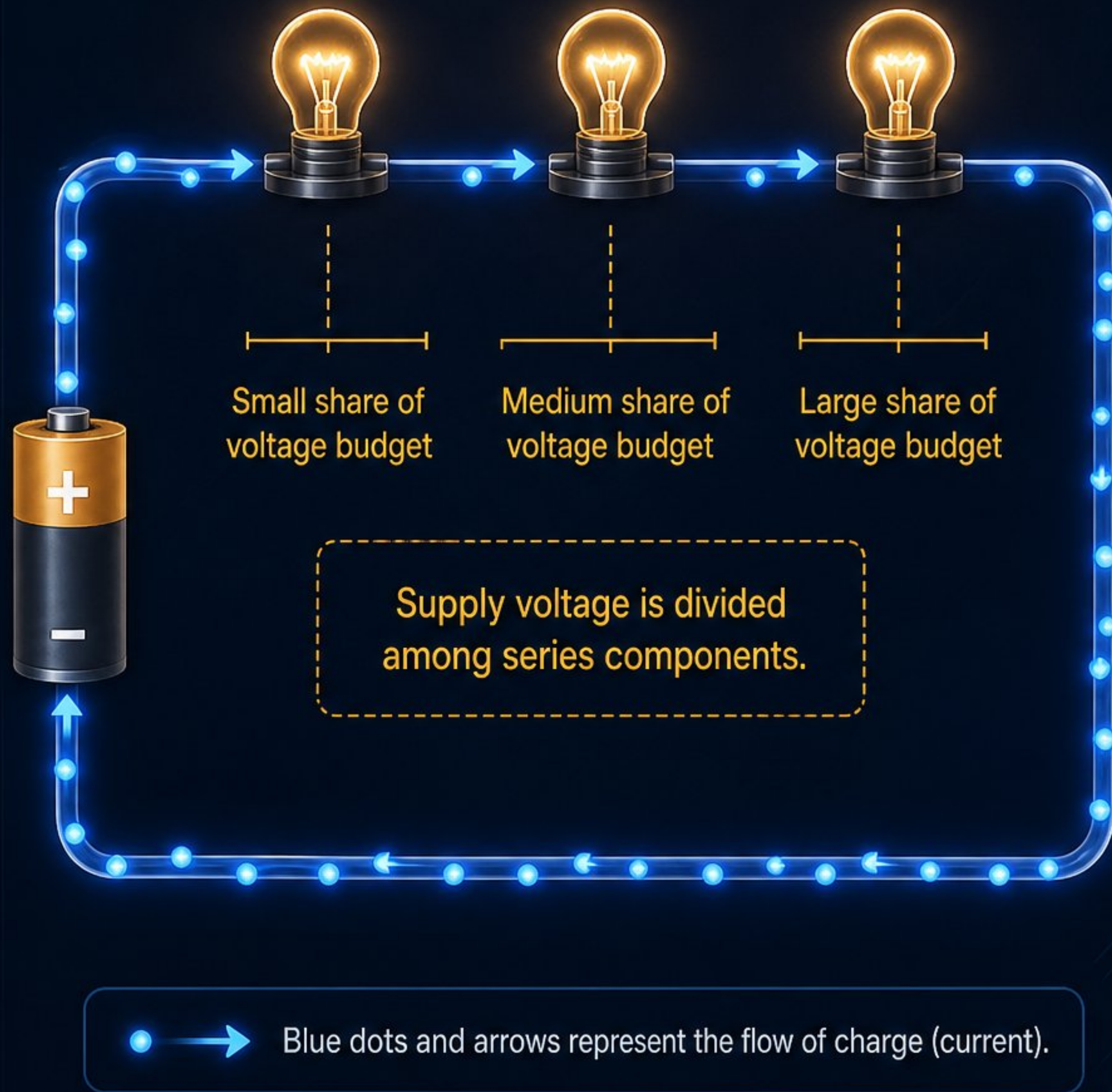
Getting Hands-On: Your Ohm's Law Laboratory

- - Build a simple DC circuit with a battery, resistor, and wires
- - Measure voltage with a voltmeter placed in parallel
- - Measure current with an ammeter connected in series
- - Plot collected V-I data to find the line's slope
- - Confirm the slope matches the resistor's known ohmic value



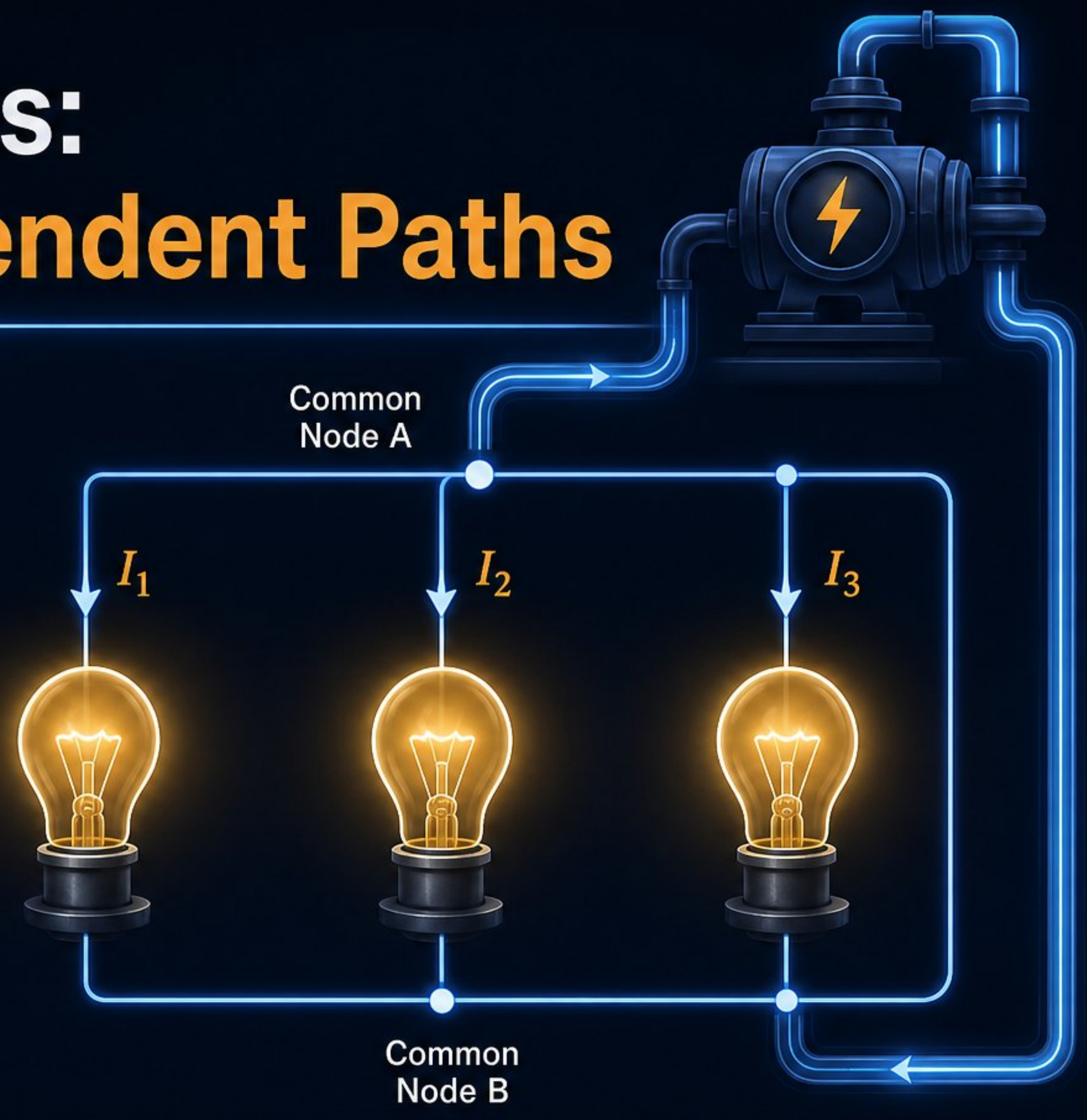
Series Circuits: A Single Path for Current

- Only **one path** for current: current is identical through every component.
- **Voltage divides**: the supply voltage is split among series components.
- **Higher resistance** gets a larger share of the voltage budget.
- Adding more bulbs increases total resistance, **lowering total current.**
- An open circuit anywhere **breaks the entire path** – all or nothing.



Parallel Circuits: Multiple Independent Paths

- Parallel branches share two common nodes, creating multiple paths for current.
- Voltage is identical across every parallel branch.
- Total current equals the sum of branch currents (Kirchhoff s Current Law).
- Adding a parallel path reduces total resistance and increases total draw.
- Identical bulbs in parallel shine equally bright, but drain the battery faster.

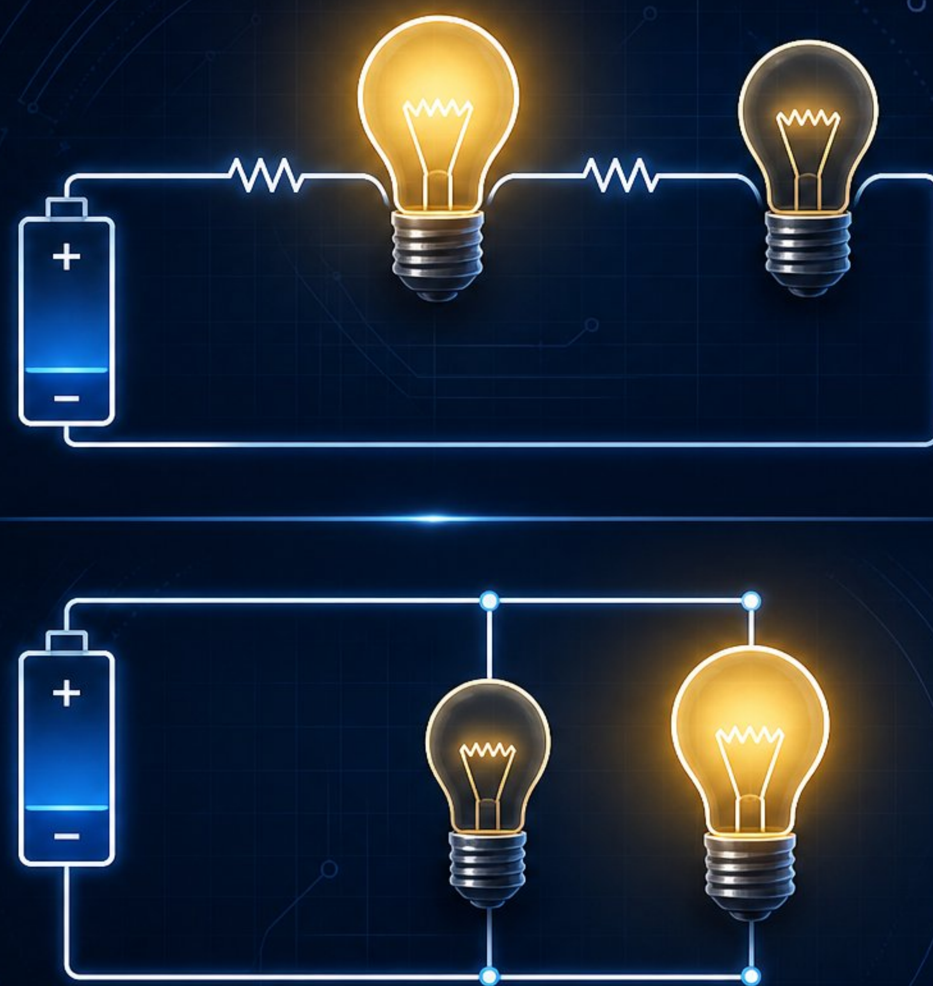


Total current equals the sum of branch currents.

$$I_T = I_1 + I_2 + I_3$$

Diagnosing Brightness: Applying the Model to Lamps

- Brightness reflects power ($P=V\times I$), not current or voltage alone. High-wattage bulbs have lower filament resistance.
- Series puzzle: the lower-wattage bulb (higher R) dissipates more power and glows brighter.
- Parallel puzzle: the higher-wattage bulb (lower R) draws more current, dissipates more power, and glows brighter.
- Use the PhET sim to test predictions—never rely on brightness heuristics without full circuit analysis.

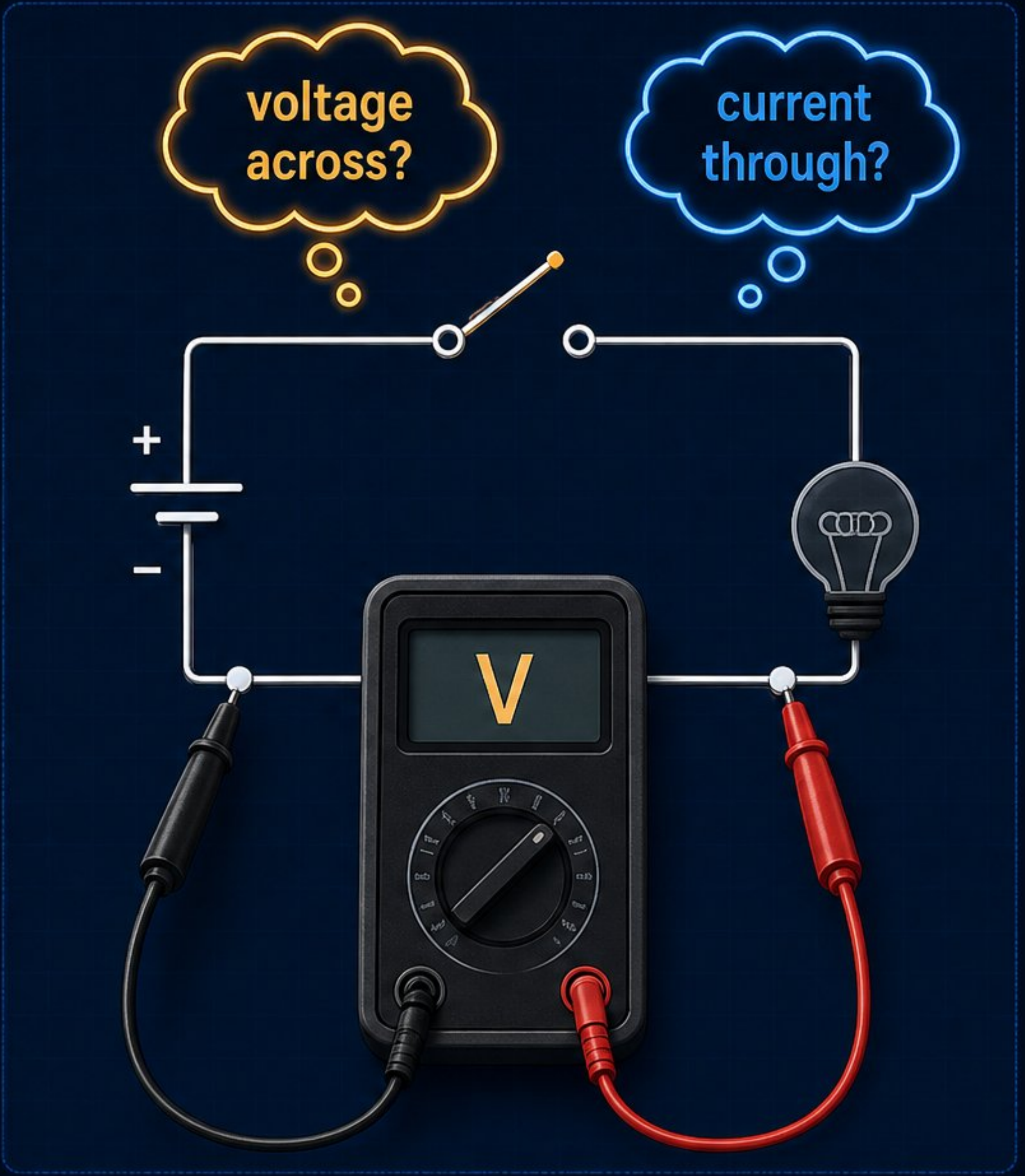


Energy and Power:
Where the Circuit Does Work

- Power (P) is the rate of energy transfer; $P = V \times I$
- Joule heating: resistors convert electrical energy into thermal energy
- Appliance labels tell a story: *V*, *A*, and *W* are connected
- Example: A **120V, 1800W** hair dryer draws ***15A***
- Overloading parallel circuits draws too much total current—dangerous

Troubleshooting and Testing Your Mental Model

- Before calculating, **predict**: will the change increase or decrease V, I, or P?
- **Don't confuse** "voltage across" with "current through"; know open vs. short.
- **Use a voltmeter** to diagnose a dead circuit; a wire has negligible voltage drop.
- **Self-check:** Adding a third parallel bulb increases total current, dims none.
- **Rely on Ohm's Law** and conservation of charge, not intuition.



Summary, Key Takeaways, and Your Next Steps

– A closed path is mandatory;
current is conserved, never consumed.

– Voltage drives the flow;
resistance limits the flow.

– Ohm's Law ($V=IR$) bridges
qualitative models and quantitative analysis.

– Series and parallel patterns are
the building blocks of all circuits.

– These core concepts extend to
capacitors, semiconductors, and AC systems.