CIRCUITS DAY 4: KIRCHHOFF & REAL BATTERIES

WARMUP **Unit 9 Pays Off Again**

On the potential map, any closed walk nets zero: $\oint E \cdot dl = 0$. A circuit loop IS a closed walk on that map. What must the voltage changes around any loop therefore sum to?

KIRCHHOFF'S TWO RULES + THE REAL BATTERY

Junction rule (charge conservation): current in = current out.

Loop rule (single-valued potential): $\Sigma\Delta V$ around any loop = 0. Battery – to +: $+\varepsilon$. Through a resistor WITH the current: $-IR$.

Real battery: an EMF ε in series with internal resistance r. Terminal voltage **$V_{term} = \varepsilon - Ir$** sags under load; $I = \varepsilon/(R + r)$.

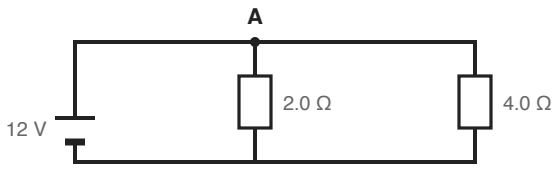
WE DO **Exercise 1: One Loop, Fully Audited**

$\varepsilon = 12$ V, $r = 0.5\ \Omega$, external $R = 5.5\ \Omega$. **(a)** $I = \varepsilon/(R+r)$ = _____. **(b)** $V_{term} = \varepsilon - Ir$ = _____. **(c)** Write the full loop sum $+12 - I(0.5) - I(5.5)$ and show it hits zero.

TWO LOOPS, AND BATTERY ECONOMICS

WE DO Exercise 2: Two-Loop Setup

A 12 V battery feeds node A; from A, a 2.0 Ω resistor returns to the battery, and separately a 4.0 Ω resistor also returns. Write the junction equation at A and one loop equation per branch, then solve: I_2 = _____, I_4 = _____, I_battery = _____.



YOU DO Exercise 3: The Sagging Battery

A battery reads 9.0 V open-circuit but only 8.0 V while delivering 2.0 A. Find its internal resistance r.

CALC Exercise 4: Maximum Power Transfer

P delivered to R is $P(R) = \varepsilon^2 R/(R+r)^2$. Differentiate with respect to R, set dP/dR = 0, and show the load that extracts maximum power is R = r. (Quotient rule; the algebra collapses fast.)

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Loop Current

$\varepsilon = 9.0$ V, $r = 0.5\ \Omega$, $R = 4.0\ \Omega$. Find I.

P2 Terminal Voltage

For P1's circuit, find the terminal voltage of the battery.

P3 Waste Heat

For P1's circuit, find the power wasted inside the battery (I^2r) and the power delivered to R. What fraction of the total reaches the load?

P4 Find the EMF

A battery with $r = 0.25\ \Omega$ delivers 4.0 A to a $2.75\ \Omega$ load. Work backward around the loop to find ε — then state what a voltmeter across the terminals reads during this delivery.