

Circuit analysis (for AP Physics C Electricity and Magnetism)

Use no more steps than necessary!

- Understand the situation.
 - Draw **large** circuit **diagram**, expressing circuit in terms of ideal batteries (pure emfs), ideal wires, and ideal resistors. A battery that has an internal resistance can be drawn as a pure emf in series with a pure resistance.
 - Label** all **givens** (numerical values, e.g. 2 A and 3.75 Ω).
 - Visibly **indicate quantities to be found** (e.g. dashed boxes).
- Indicate all equipotential sets using **highlighter** pens.
 - Ideal wire drops no potential.
 - You can choose to identify a reference potential position (“ground”) labeled “0 V.”
 - Label any known potentials repeatedly at various locations in each equipotential set.
- Collapse series/parallel **combinations**, computing R_{EQ} , C_{EQ} , or L_{EQ} and **redrawing** labeled circuit to **illustrate each incremental simplification** made.
- Cycle through the following boxes to fill in as many quantities as possible (or as needed). (For simpler problems, cycling through only 4b and 4d often suffices).

4a: Charge

$$Q$$

Cycle through the following considerations to fill in as many initially unknown charges as possible (or as needed).

- $Q = C|\Delta V_C|$
- Capacitors in series have the same charge.
- Capacitors in parallel act as proportional charge dividers (e.g. a capacitor having 10% of equivalent parallel capacitance carries 10% of charge).

4b: Current

$$I$$

Cycle through the following considerations to fill in as many initially unknown currents as possible (or as needed).

- $|I| = \frac{|\Delta V_R|}{R}$ (current flows toward lower V)
- Continuity:
 - Same current when in series
 - Junction rule

4c: Time-rate of change of current

$$\frac{dI}{dt}$$

Cycle through the following considerations to fill in as many initially unknown rates of change of currents as possible (or as needed).

- $\mathcal{E} = -L \frac{dI}{dt}$, $|\Delta V_L| = L \left| \frac{dI}{dt} \right|$
- Continuity:
 - Same rate of change of current in series
 - Junction rule

4d: Potential difference

$$\Delta V$$

Cycle through the following considerations to fill in as many initially unknown potential differences or potentials as possible (or as needed).

- Constitutive relationships (potential difference relationships, including definition of a battery)
- Ideal wires have no resistance and, thus, drop no potential.
- [Partial] loop rule: Recognize parallel portions of circuits.
- Resistances in series can be analyzed as potential difference dividers.

If step 4 fails to provide enough information to obviously solve the problem, move on to step 5.

- Explicitly **write out Kirchoff's loop and junction rules** with only the remaining unknown quantities represented using algebraic variables (all other quantities “plugged in”). Alternatively, apply **nodal analysis** or **mesh analysis**. Solve using tedious **algebraic methods** (e.g. **matrix** methods if necessary).