Circuit analysis (for AP Physics C Electricity and Magnetism)

Use no more steps than necessary!

1. Understand the situation.
    (a) Draw **large** circuit **diagram**, expressing circuit in terms of ideal batteries (pure emfs), ideal wires, ideal resistors, ideal capacitors, and ideal inductors. A device that has an internal resistance can be drawn as an ideal device in series with a pure resistance.
    (b) **Label** all **givens** (numerical values, e.g. $2\ \mathrm{A}$ and $3.75\ \Omega$).
    (c) Visibly **indicate quantities to be found** (e.g. dashed boxes).
2. Indicate all equipotential sets using **highlighter** pens.
    (a) Ideal wire drops no potential.
    (b) You can choose to identify a reference potential position ("ground") labeled "$0\ \mathrm{V}$."
    (c) Label any known potentials repeatedly at various locations in each equipotential set.
3. Collapse series/parallel **combinations**, computing R_{EQ}, C_{EQ}, or L_{EQ} and **redrawing** labeled circuit to **illustrate each incremental simplification** made.
4. 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).

1. $Q = C|\Delta V_{\mathrm{C}}|$
2. Capacitors in series have the same charge.
3. 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).

1. $|I| = \frac{|\Delta V_{\mathrm{R}}|}{R}$ (current flows toward lower V)
2. Continuity:
    a. Same current when in series
    b. Junction rule

4c: Time-rate of change of current

$$\frac{\mathrm{d}I}{\mathrm{d}t}$$

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

1. $\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$, $|\Delta V_{\mathrm{L}}| = L\left|\frac{\mathrm{d}I}{\mathrm{d}t}\right|$
2. Continuity:
    a. Same rate of change of current in series
    b. 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).

1. Constitutive relationships (potential difference relationships, including definition of a battery)
2. Ideal wires have no resistance and, thus, drop no potential.
3. [Partial] loop rule: Recognize parallel portions of circuits.
4. 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.

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).