

## How To Solve R/L/C Circuits

Circuits which have some combination of resistors, capacitors and inductors can usually be “solved” using Kirchoff’s Loop Rule. Generally you are asked to find  $Q(t)$  or  $I(t)$  (or both), and the idea is to use the Loop Rule to get a differential equation whose solution is what you need. Please see the Kirchoff How-To for more details on some of the steps.

1. Identify loop or loops in the circuit where you want to find  $Q(t)$  and/or  $I(t)$ . Draw and name currents, and label the charges on capacitor plates at a given moment in time (for instance, when switch is opened, etc.).
2. “Walk around the loop”, and for each circuit element you encounter, write down the correct  $\Delta V$  across the element:
  - For a battery:  $\varepsilon$ , positive if walking from  $-$  to  $+$ . (Note that for an AC power supply this is sinusoidally varying, i.e.  $\varepsilon_0 \sin \omega t$ ).
  - For a resistor:  $-IR$  if walking in the direction of the current.
  - For an inductor:  $-LdI/dt$  if walking in the direction of the current.
  - For a capacitor:  $-Q/C$  if walking from  $+$  to  $-$  side of the capacitor.

For any of these, sign is the opposite if walking around in opposite the direction specified above. Note that for this type of problem we are usually *not* talking about the steady-state case where current through a capacitor is zero; typically these are transient or oscillatory situations for which there’s effective current through a capacitor. If it *is* steady-state, however, you can assume zero current through a capacitor (open circuit), and no effect on the circuit from an inductor.

3. Substitute  $I = dQ/dt$  if appropriate (for instance, if you’re trying to find  $Q(t)$ .) This equation may have a negative sign,  $I = -dQ/dt$ , for decreasing charge in the picture you have drawn (for instance, charge leaving a capacitor).
4. Solve the resulting differential equation for the quantity you want. Sometimes this will be straightforward, and sometimes not.