Lesson 13i: RC Circuits

If you have a circuit with both resistors and capacitors, you call it (not surprisingly) a **RC circuit**.

- Because of the capacitor, the circuit will behave in a particular way.
  - At first, with the capacitor ***uncharged***, DC current will flow through it without any problem.
  - This means that we can just do calculations based on the resistors as if the capacitor was not even there. You can go ahead and use formulas like V = IR.
  - Over a period of time, the voltage across the capacitor will cause it to build up charge. As this happens the amount of current passing through the capacitor will decrease.
  - Eventually the capacitor will be fully charged, with the same voltage as the battery. Now, no current will flow through the circuit. You can figure out how much charge is stored using Q = CV.
- When we reach the point when the capacitor is fully charged (after the circuit has been turned on for a while), we can say that the circuit is showing **steady-state behavior.**

Once a circuit is steady-state, you may need to figure out a few things about the capacitors (remember, we are now ignoring any resistors in the circuit).

- The good news is that the rules for capacitors are just the opposites of what you did for resistors.
  - In ***series***, you can find the equivalent capacitor by adding the reciprocals...

$$\frac{1}{C_T}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

  - In ***parallel***, you find the equivalent capacitor by adding them directly...

$$C_T=C_1+C_2+C_3$$

It is possible that you might also want to know the energy that is stored in the capacitor once it has reached a steady-state. This can be quickly calculated using...

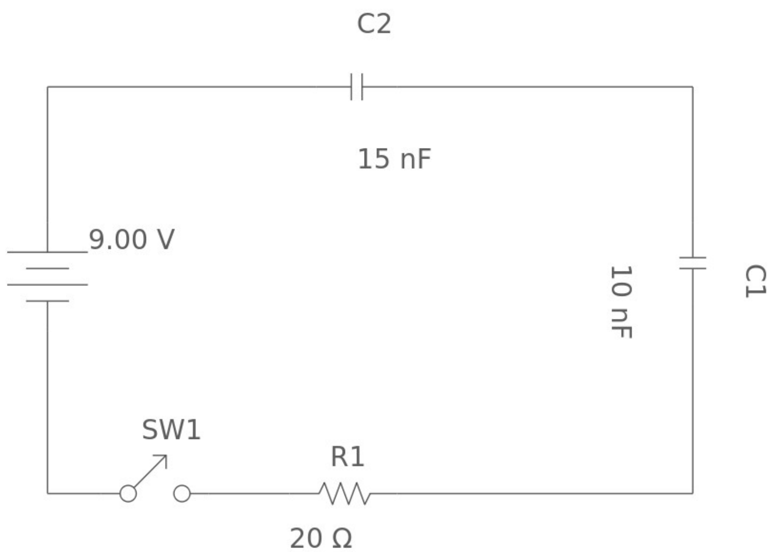
$$E=\frac{1}{2}CV^2$$

E = energy (J)
C = capacitance (F)
V = voltage (V)

Example 1: We have a circuit made up of a 20 Ω resistor, a 10 nF capacitor, and a 15 nF capacitor. They are connected in series to a 9.0 V battery and a switch is currently in the off (open) position.

a) **Sketch** a schematic (circuit) diagram of this situation.
b) **Determine** the equivalent capacitance of the two capacitors.
c) If the switch is turned on (closed), **determine** the initial current in the circuit (before it reaches steady-state behavior).
d) After the circuit has been on for a while and reached steady-state, **determine** the charge and energy stored in the equivalent capacitance.

a) Your answer might not look exactly like this, but the general idea is...



b) Since the two capacitors are in series...

$$\frac{1}{C_T}=\frac{1}{C_1}+\frac{1}{C_2}$$
$$\frac{1}{C_T}=\frac{1}{10\text{e-}9}+\frac{1}{15\text{e-}9}$$
$$C_T=6.0\text{e-}9\,F=6.0\,nF$$

c) When it is first turned on, we can ignore the capacitors since they'll just let the current go through at first.

$$I=\frac{V}{R}$$
$$I=\frac{9.00}{20}$$
$$I=0.45\,A$$

d) Two quick calculations here...

$$Q=CV$$
$$Q=6.0\text{e-}9(9.00)$$
$$Q=5.4\text{e-}8\,C$$

$$E=\frac{1}{2}CV^2$$
$$E=\frac{1}{2}6.0\text{e-}9(9.00^2)$$
$$E=2.43\text{e-}7\,J$$