

Source: [KBhPHYS201CircuitsIndex](#)

1 | Capacitors

1.1 | Capacitors vs. Batteries

Batteries => Converting PE_{chem} => Electrical energy

Capacitors => Converting PE_{elec} => Electrical energy

When you are discharging a battery, they remain at constant voltage until they are used up, at which point the voltage drops like a plate.

When you are discharging a capacitor, there is a linear fall in voltage that is constant.

Charge remaining: capacitance times voltage

1.2 | Energy on a Capacitor

A little bit disorganized

Energy stored on a capacitor: $E = \frac{V_c \cdot Q}{2}$.

Charge on a capacitor: $Q = C \times V_c$

Farads: $F = \frac{C}{V}$

So, putting this together, the energy stored on a capacitor would be...

$$\text{Definition 1} \cdot \text{Energy stored in a capacitor } E = \frac{V \times Q}{2} = \frac{CV^2}{2}$$

as $Q = C \times V_c$

$Q_{cap} \propto V$. In fact $Q_{cap} = C \times V_c$.

1.3 | Capacitors interacting with Resistance

As you increase the [KBhPHYS201Resistance](#), the a capacitor of the same capacitance would charge slower. ("Less charge flows in")

As you fix the Resistance, the capacitor of a higher capacitance would charge slower. ("Need more charge to fill")

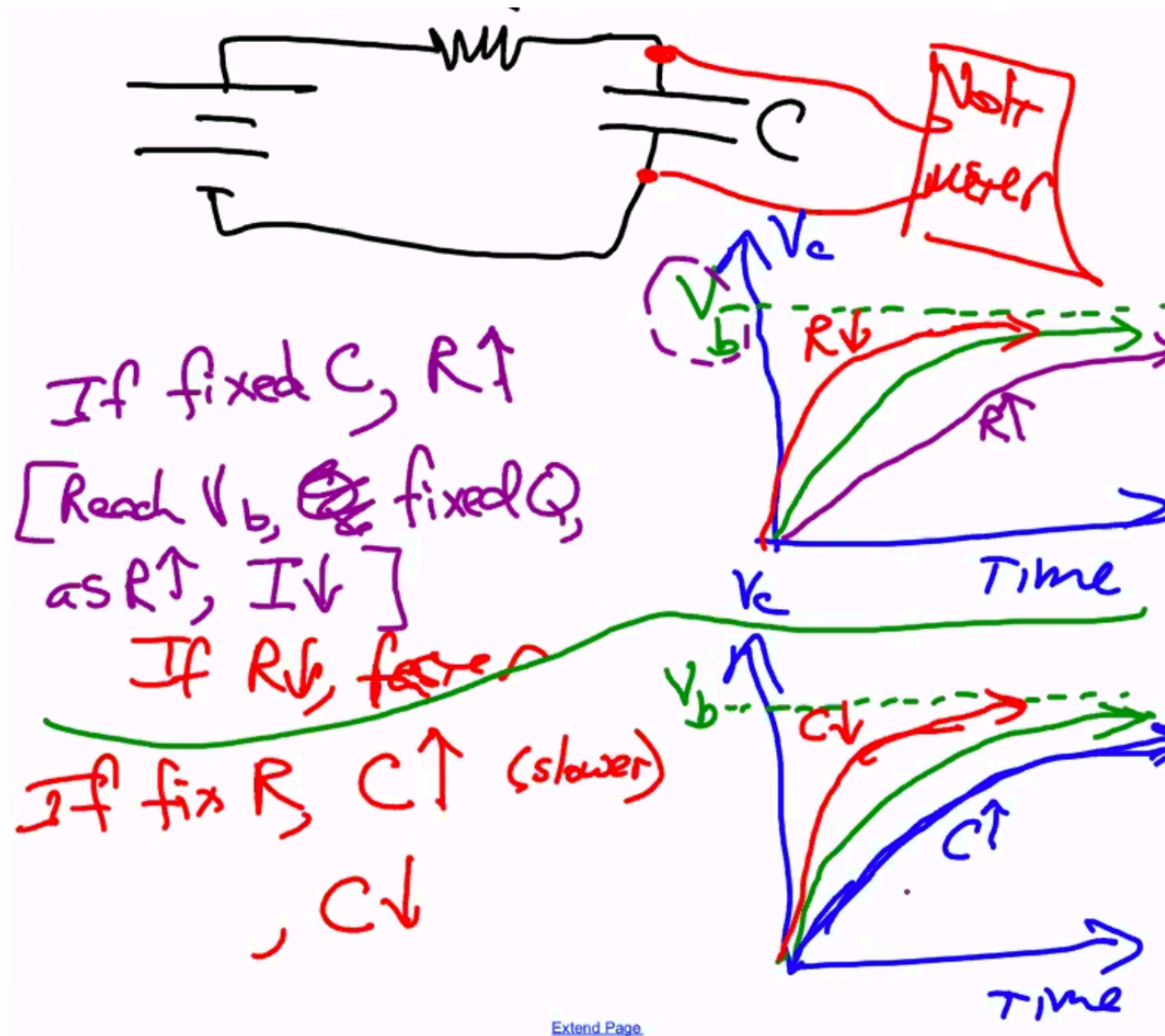


Figure 1: Screen Shot 2020-09-30 at 10.42.44 AM.png

Charging time is in fairly good agreement with *resistance times capacitance*.

So... #disorganized

Experimentally, "Charging time", $\tau \approx R \times C$.

Let's check the units!

- $V = IR$
- $R = \frac{V}{I}$
- So $R = \omega = \frac{V \cdot s}{Q}$
- $Q = CV$
- So $\frac{Q}{V} = C$

Hence, $R \times C = \frac{V \cdot s}{Q} = \frac{Q}{Q}$, indeed, has a unit Seconds!

1.4 | Equations modeling charging a capacitor

Definition 2 · **Time Constant Tau** $RC = \tau$ — time constant to be able to change the capacitor to a useful voltage; aka how much does the capacitor need to noticeably charge/discharge.
where R is the resistance, C is the capacitance

Now that we have this value, we could also represent the full charge process using the equations as follows:

Definition 3 · **Current in circuit as you charge a capacitor** $I(t) = \frac{V_b}{R} \times e^{-\frac{t}{RC}}$
where V_b is the battery voltage, t is time elapsed, R is resistance, and C is the capacitance

As you start to charge a capacitor, the current starts at $\frac{V_b}{R}$ — current just without the resistor. Then, it will slowly drop down to 0.

Definition 4 · **Voltage before and after a capacitor as you charge a capacitor** $V(t) = V_b \times (1 - e^{-\frac{t}{RC}})$
where V_b is the battery voltage, t is time elapsed, R is resistance, and C is the capacitance

#disorganized

1.5 | Capacitors in series and parallel

Helpful to see: [\[KBhPHYS201CombiningResistors\]](#)

1.5.1 | Capacitors in Parallel

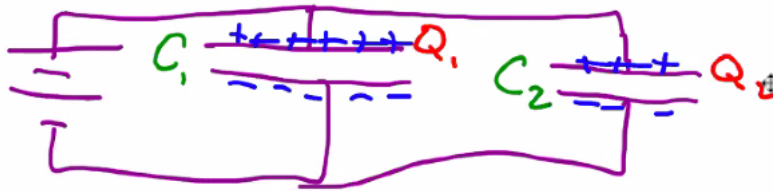


Figure 2: Screen Shot 2020-10-07 at 10.20.06 AM.png

$$Q_{tot} = Q_1 + Q_2.$$

And, because of the fact that $C = \frac{Q}{V}$, $V \times C_{eq} = V \times C_1 + V \times C_2$

Dividing V out of the previous equations $C_{eq} = C_1 + C_2$.

Capacitors in parallel act like resistors in parallel.

1.5.2 | Capacitors in Series



Figure 3: Screen Shot 2020-10-07 at 10.23.08 AM.png

Because of the fact that the middle wire does not carry any charges, it is “neutral” and simply polarized — making Q_1 equaling Q_2 .

Why is this? If the middle bit is neutral, the Q^+ on one end would equal to the Q^- on the other. Correspondingly, the other side of the plates of the capacitor would have the opposite of the same values Q^- and Q^+ on the neutral middle plate.

By the transitive property, $Q_1 = Q_2$.

Because $V_1 + V_2 = V_b$ — see [KBhPHYS201CombiningResistors](#) & $C = \frac{Q}{V}$, $\frac{Q_1}{V} + \frac{Q_2}{V} = \frac{Q_{tot}}{V}$.

So