

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")

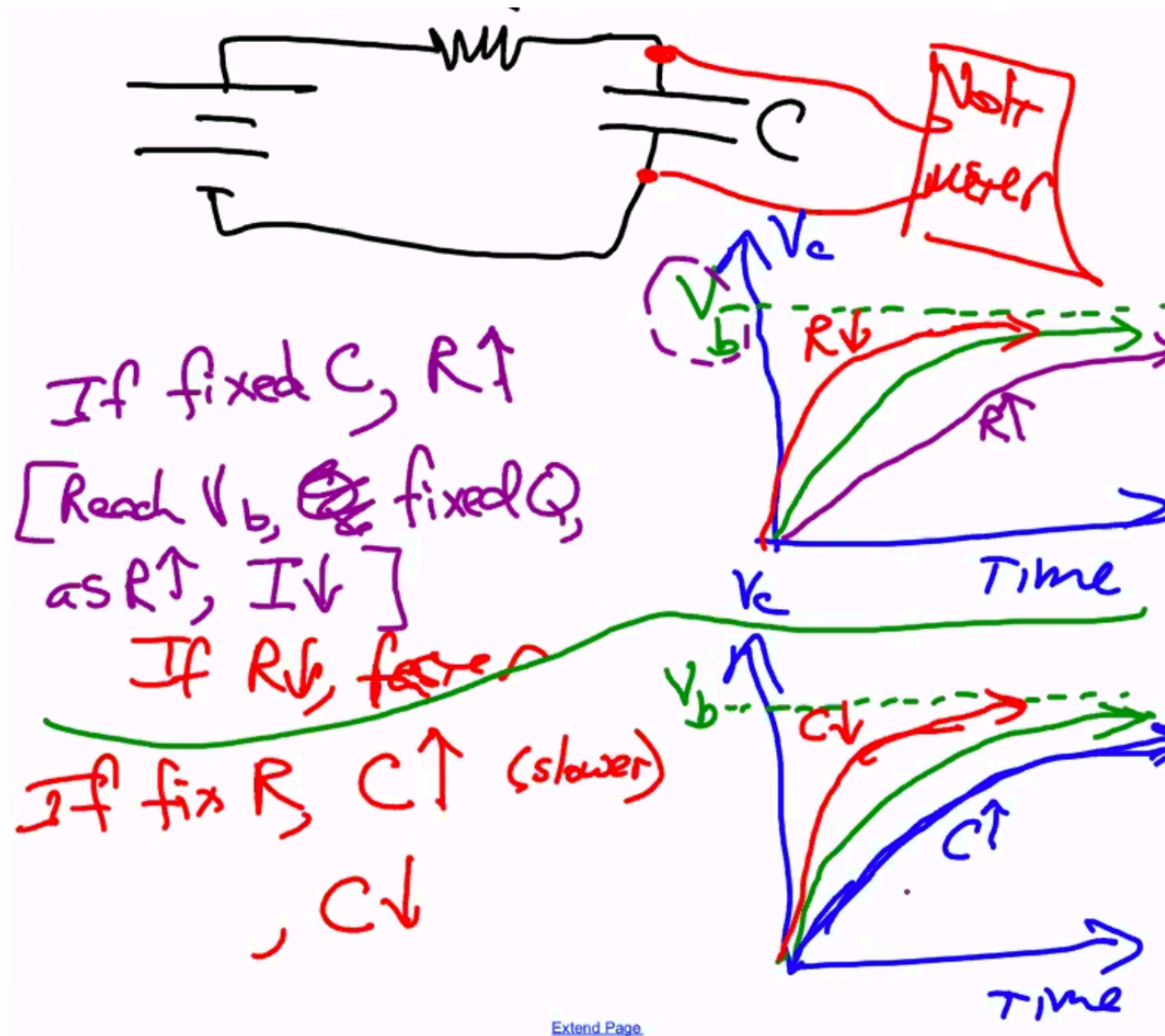


Figure 1: Screen Shot 2020-09-30 at 10.42.44 AM.png

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