Basic Physic Circuit Formulas

For diagrams, see: https://web.iit.edu/sites/web/files/departments/academic-affairs/academic-resource-center/pdfs/RCcircuits.pdf
Common terms:
- **Voltage** is the difference in charge between two points.
- **Current** is the rate at which charge is flowing.
- **Resistance** is a material's tendency to resist the flow of charge (current).
- **Amps** Amount of current flowing over a period

In water terms:
- Water = Charge (measured in Coulombs)
- Pressure = Voltage (measured in Volts)
- Flow = Current (measured in Amperes, or "Amps" for short)
- Hose Width = Resistance

$$V = I \cdot R$$

Where:
- V = Voltage in volts
- I = Current in amps
- R = Resistance in ohms
- A = amperage (coulombs per second) aka volume moved in a second. Breakers use this to prevent wires overheating.
- W = Watt is the amount of energy consumed $w = V.A$, electricity at work is the pressure times the volume

Series vs Parallel Circuits

Series:
- V changes as it flows through resistance components
- I stays the same
- V = $v_1 + v_2 + ...$
Parallel:
- V stays the same
- I changes through the components
- $v = v_1 = v_2 = v_3$

Resistance Stacking

Series of Rs add up:

$$R = R_1 + R_2 + \ldots$$

Parallel Rs have the relationship:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

Kirchoff's laws:

Voltage law:

- In a complete loop, total voltage change is 0
  - This means that V=IR_1 and V=IR_2 in a system where there are 2 parallel resistors.
  - In series of resisters, V = IR_1 + IR_2

Current law:

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- Current coming out of a point is equal to current going in
    - I_1 = I_2 + I_3 if there are 2 parallel resistors
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Capacitors

In a basic RC circuit:
The Capacitance of Capcitor is proportional to $\frac{A}{l}$ where A is area and l is the distance
- C of the system adds the same way as R in parallel and series circuits
- $C = \frac{Q}{V}$ in the units of farads. It is the ratio of charge Q to potential difference V
- 1 Farad capacitor holds 1 coulomb of charge at 1 volt.
- 1 coulomb = $6.25.e^{18}$ electrons
- 1 amp is rate of 1 coulomb per 1 second
Capacitor has voltage proportional to charge

$$V = \frac{Q}{C}$$

This means that

$$V - IR - \frac{Q}{C} = 0$$

$$V = R\frac{dQ}{dt} + \frac{Q}{C}$$

RC is the time constant of the circuit

Driving point impedence

In a capacitor, we have:

$$C = \frac{Q}{V}$$

The time-series functions are

$$q(t) = Cv(t)$$

Taking the derivative:

$$i(t) = C\frac{dv(t)}{dt}$$

Where I/i(t) is the current in amperes since we know that $I = \frac{dQ}{dt}$. This just means t coulombs per second give us the energy flow aka amps.
Now using Laplace transforms:

$$I(s) = CsV(s) - Cv(0)$$

Which (considering initial voltage to be zero) leads to:

$$R_c(s) = \frac{V(s)}{I(s)} = \frac{1}{Cs}$$

$R_C(s)$ is the driving point impedance of the capcitor, allowing analysis of the capacitor similar to a resistor, with value of $\frac{1}{Cs}$ ohms