Chapter 28 Fundamentals of Circuits

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Kirchhoff's Laws and the Basic Circuit

Because charge is conserved, for junctions,

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

Because energy is conserved, a charge that moves around a closed path has $\Delta U_{\text{elec}} = 0$.

$$\Delta V_{\text{loop}} = \sum (\Delta V)_i = 0$$

Energy and Power

The rate at which the battery supplies energy to the charges is

$$P = \Delta V_R \times I = I^2 \times R = \frac{(\Delta V_R)^2}{R}$$

where P is the power in watts, V is the voltage, I is the current, and R is the resistance.

$$1\,W \equiv 1\,J\,/\,s$$
$$1\,A \equiv 1\,C\,/\,s$$

Series Resistors

$$R_{\text{eq}} = R_1 + R_2 + R_3 + \cdots \quad \text{(sequential resistors)}$$
$$\Delta V_{\text{eq}} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \cdots \quad \text{(sequential resistors)}$$

Real Batteries

Real batteries provide a slight resistance called an internal resistance.

When a connection of very low or zero resistance is made between two points in a circuit that are normally separated by a higher resistance, a short circuit is formed which shorts out the battery. If the battery were ideal, shorting it with zero resistance would cause the current to be $I = \varepsilon/0 = \inf$. The current cannot really become infinite since the battery has an internal resistance r.

$$I_{\text{short}} = \frac{\varepsilon}{r}$$

Parallel Resistors

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \quad \text{(parallel resistors)}$$

Grounded Circuits

A circuit connected to the earth is said to be grounded, and the wire is called the ground wire. There isn't a second wire so there is no current in the wire, it is just used as a common reference point for the potential but does not in any way change how the circuit functions.

RC Circuits

Circuits with resistors and capacitors are called RC circuits.
If we use $\tau = RC$ as the time constant for how much the capacitor has been discharged,

$$Q = Q_0 e^{-t/\tau}$$

$$\Delta V_C = \Delta V_0 e^{-t/\tau}$$

There's no specific time at which the capacitor has been completely discharged, because ΔV approaches zero asymptotically, but the voltage and current will drop below 1% of their initial values at some point.

The same time constant can be used for charging a capacitor,

$$\Delta V = \varepsilon(1 - e^{-t/\tau})$$

$$I = I_0 e^{-t/\tau} \quad \text{(capacitor charging)}$$