# Chapter 28 Fundamentals of Circuits

David Robinson

## 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.

## Series Resistors

$$R_{\text{eq}} = R_1 + R_2 + C_3 + \cdots \quad \text{(sequential resistors)}$$
$$\Delta V_{\text{eq}} = \Delta V_1 + \Delta V_2 + \Delta V_3 + \cdots \quad \text{(sequential resistors)}$$

## 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

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

# Grounded Circuits

A circuit connected to the earth is sadi 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 $\Delta V$ 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,

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

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