ESC201A
Introduction to Electronics

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Circuit Fundamentals

Concepts

- Charge, Current, Voltage, Power, and Energy
- Ohm’s Law
- Kirchoff’s Current Law (KCL)
- Kirchoff’s Voltage Law (KVL)

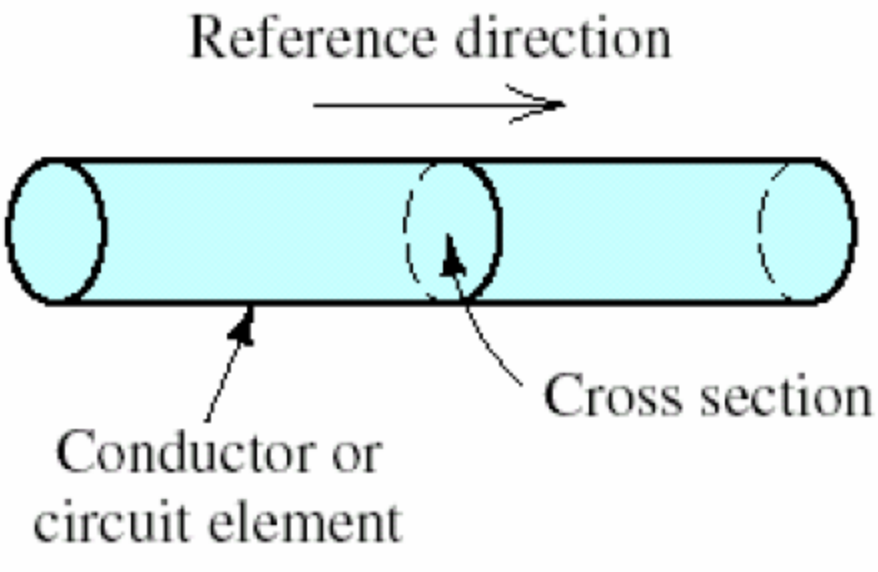
Charge

- Charge is a fundamental property of matter and is said to be conserved
  - Can neither be created nor be destroyed
- Two types of charge
  - Same charge attract and opposite repel
- Charge is designated by symbol q has unit coulombs
- Negative charge carried by a single electron is $\mathbf{-1.602\times10^{-19}}$ C
  - Smallest unit of charge that exists
- Charge flow leads to electric current

Electrical Current

- Current is simply a measure of how much charge is moved per unit of time

– Units are amperes (A), which are equivalent to coulombs per second (*C/s)*



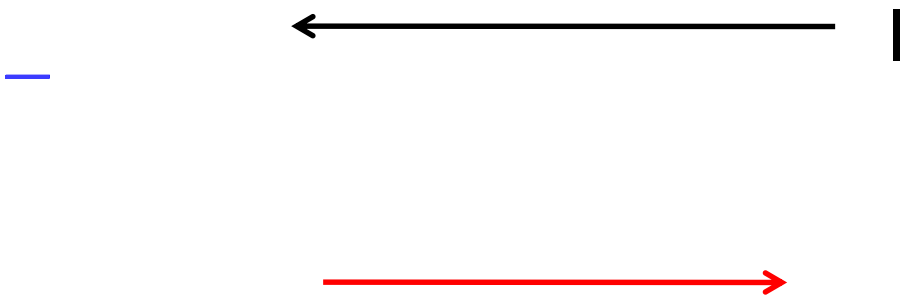
$$i(t) = \frac{dq(t)}{dt}$$

André-Marie Ampère
1775-1836

Flow of electrons through a wire or other electrical conductor gives rise to current

- Electrons are negatively charged particles

The charge per electron is **-1.602×10^{-19} *C***

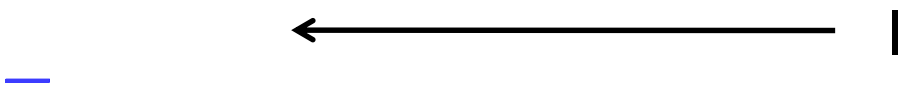


10^{16} electrons flow per second

How much current flows? $i(t) = \frac{dq(t)}{dt}$

$$I = \frac{Q}{t} = \frac{-1.6\times10^{-19}\times10^{16}}{1} = -1.6\times10^{-3}\,A$$

Current has a magnitude and a direction



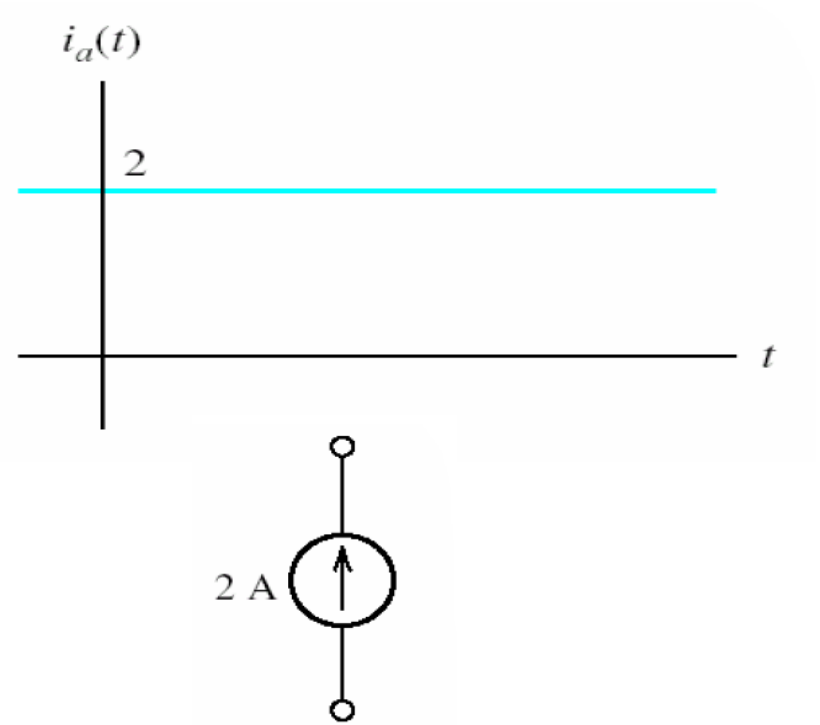
10^{16} electrons flow per second

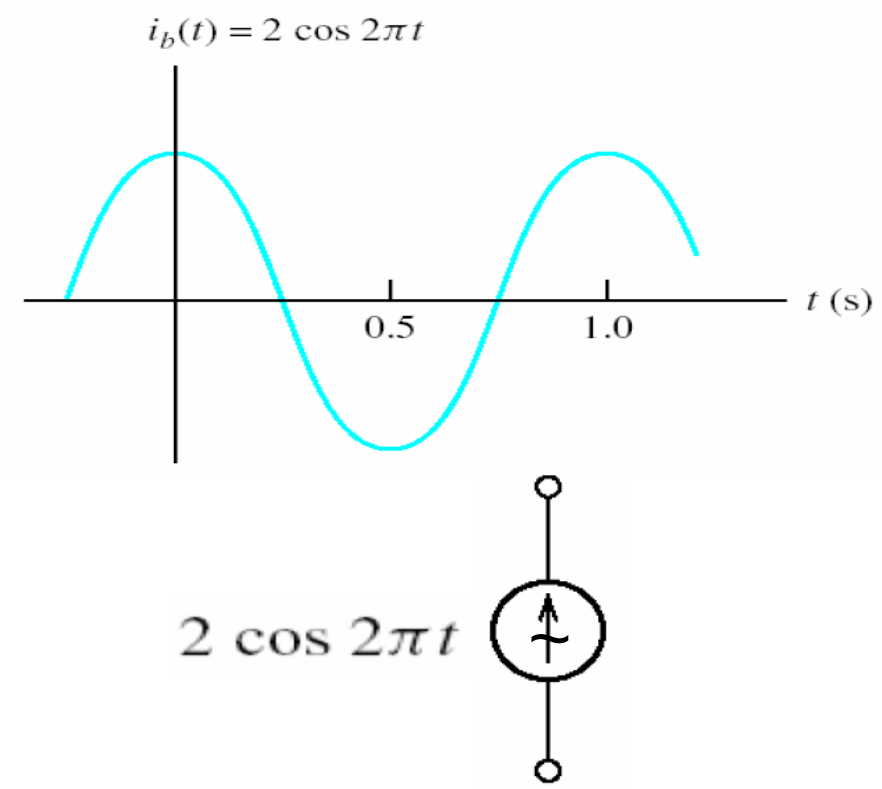
Direction of current flow is opposite to direction of electron flow

Large number of electrons have to flow for appreciable current

Direct Current (DC) & Alternating Current (AC)

When current is constant with time, we say that we have direct current, abbreviated as DC.



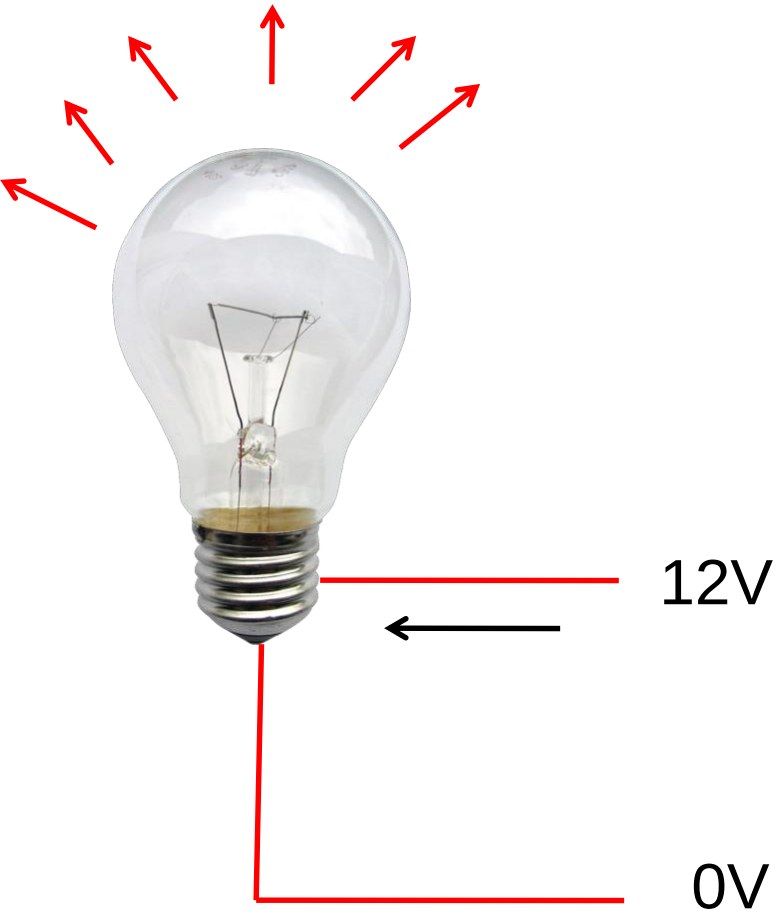


On the other hand, a current that varies with time, reversing direction periodically, is called alternating current, abbreviated as **AC**

Voltage

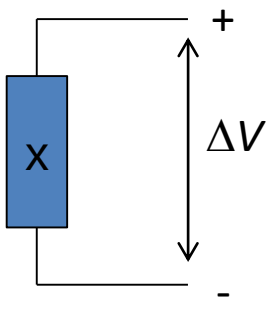
- Voltage difference causes current to flow
- Potential difference for a unit positive charge between two points: Work done to move unit positive charge between two points
- Units of Voltage: volt (V)

Alessandro Giuseppe Antonio Anastasio Volta 1745-1827

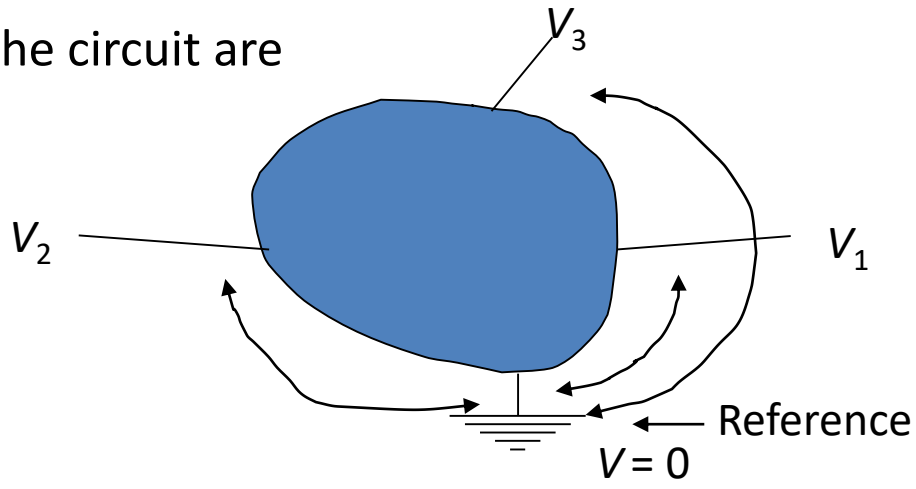


Voltage is Relative

- In practice, it is ΔV that matters



- In a circuit (system), we choose a reference
  - Reference is called “ground”
  - Rest of the voltages in the circuit are w.r.t. ground

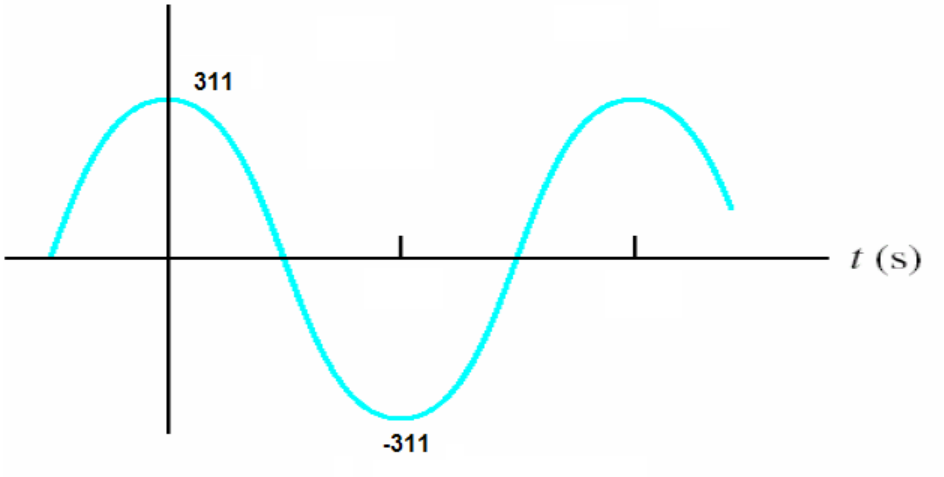


Voltage Sources

DC and AC voltages

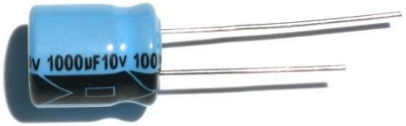
$$V_+ - V_- = 12V$$

Typically 220 V RMS, 50 Hz



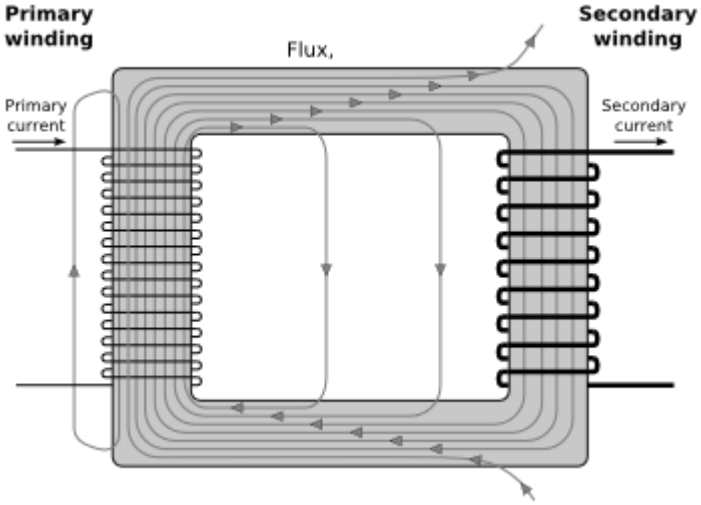
Electrical Systems are made of Voltage sources, wires and a variety of **electrical elements**

Resistor

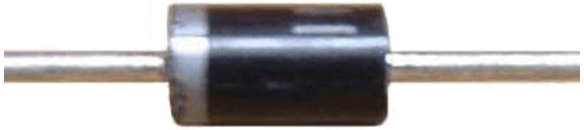


Capacitor

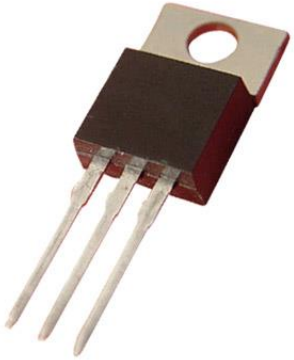
Inductor



Transformer

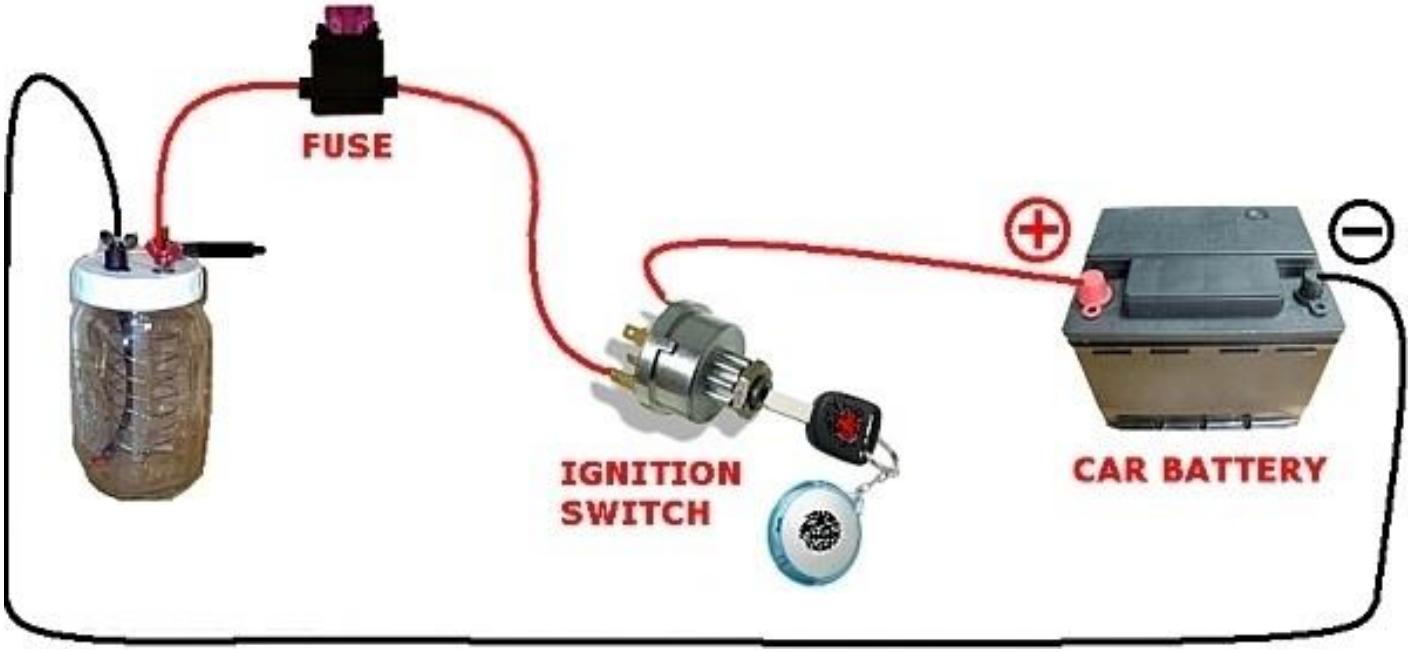


Diode



Transistor

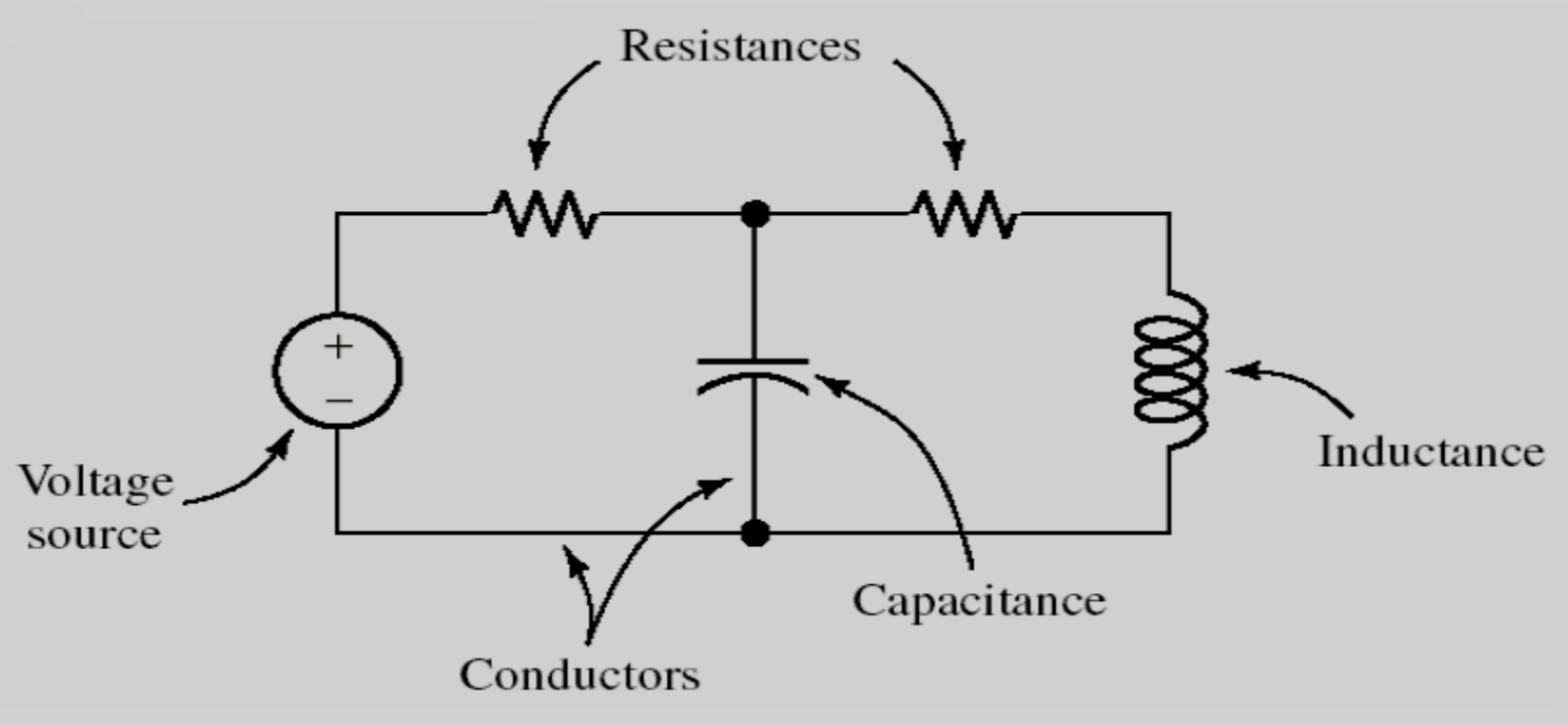
Current flows in a loop



Electrical systems are called electrical circuits

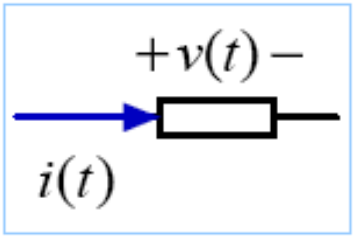
Electrical Circuit

Connection of several circuit elements in closed paths by conductors



Before we learn how to analyze and design circuits, we must become familiar with some basic circuit elements.

Resistance



$$v(t) = R \times i(t)$$

Ohm's law

The constant, *R, is called the resistance of the component and is* measured in units of Ohm (Ω)

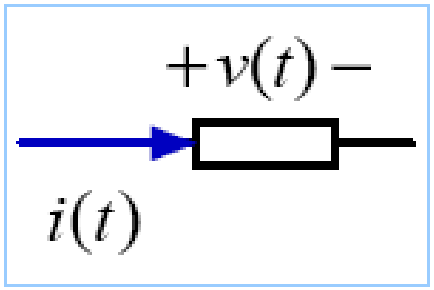
Standard Multiples of Ohm

$M\Omega$	Mega Ohm ($10^6\,\Omega$)
$k\Omega$	Kilo Ohm ($10^3\,\Omega$)

Georg Simon Ohm
1789-1854

Resistor Symbol:

Conductance



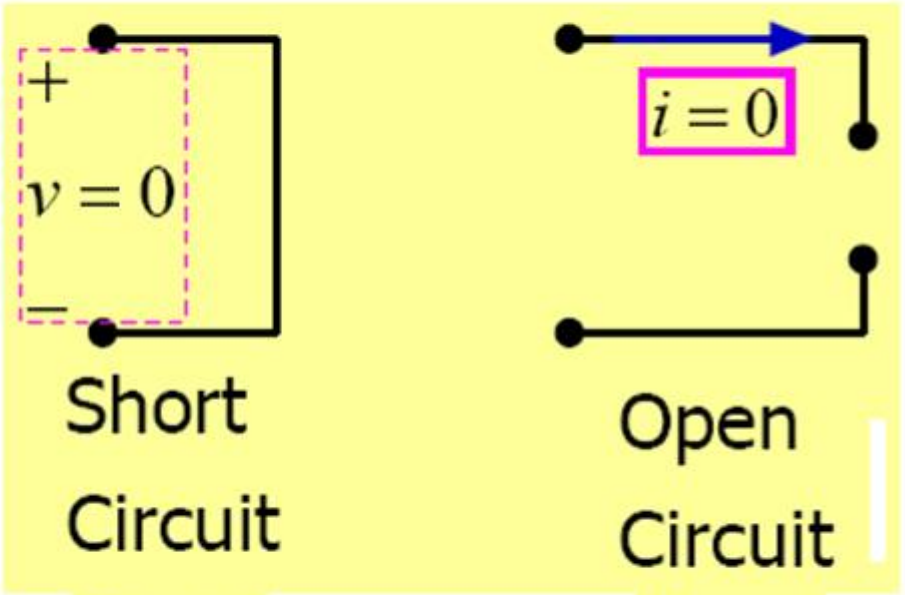
$$v(t) = R \times i(t)$$

$$i(t) = \frac{v(t)}{R} = G \times v(t)$$

Ernst Werner von Siemens
1816-1892

G = 1/R is called conductance and its unit is Siemens (S)

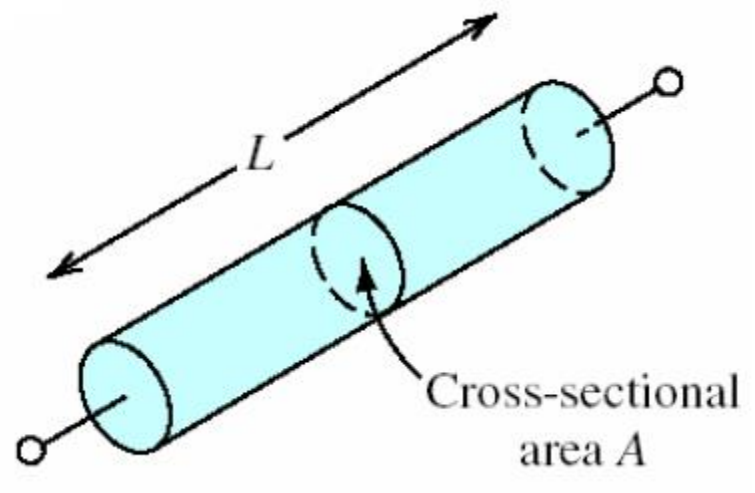
Two special resistor values



$$R = \frac{v}{i}$$

$$G = \frac{i}{v}$$

Resistance Related to Physical Parameters

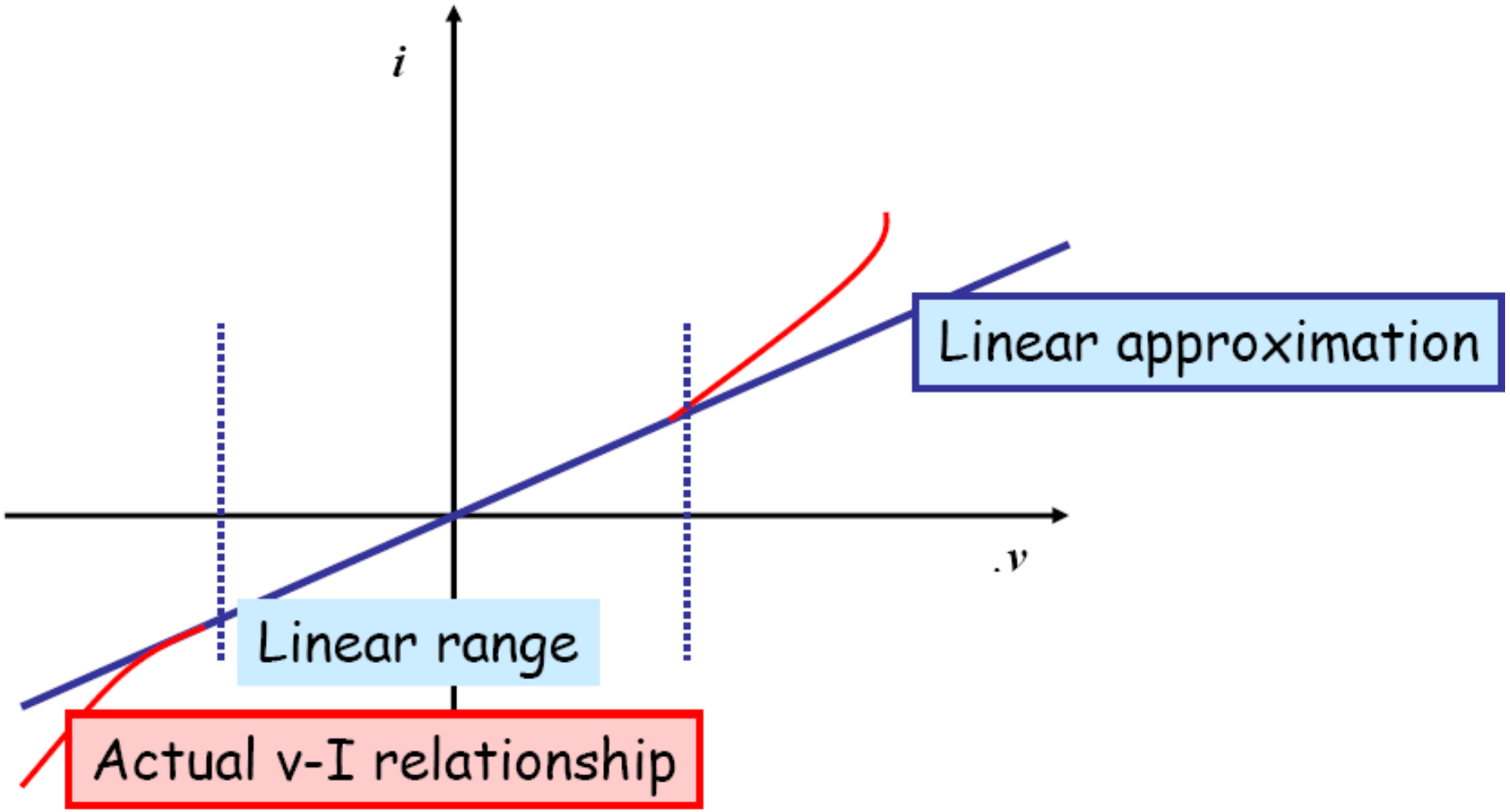


$$R = \rho \times \frac{L}{A}$$

Resistance is affected by the dimensions and geometry of the resistor as well as the particular material used

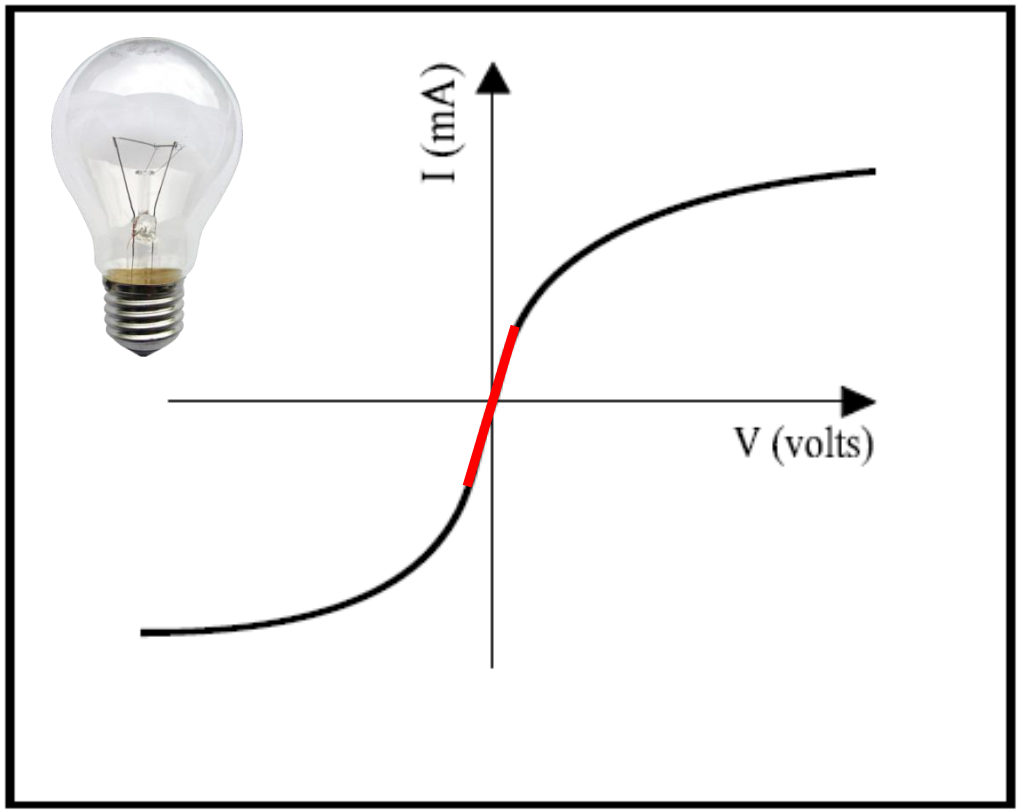
ρ is the resistivity of the material in ohm meters [Ω-m]
– Conductors (Aluminum, Carbon, Copper, Gold)
– Insulators (Glass, Teflon)
– Semiconductors (Silicon)

Any electrical element which obeys ohms law can be modeled as a resistor



Can we model an electric bulb as a resistor?

Electrical Bulb



Even though characteristics are non-linear, over a certain range, the bulb can be thought of as a resistor