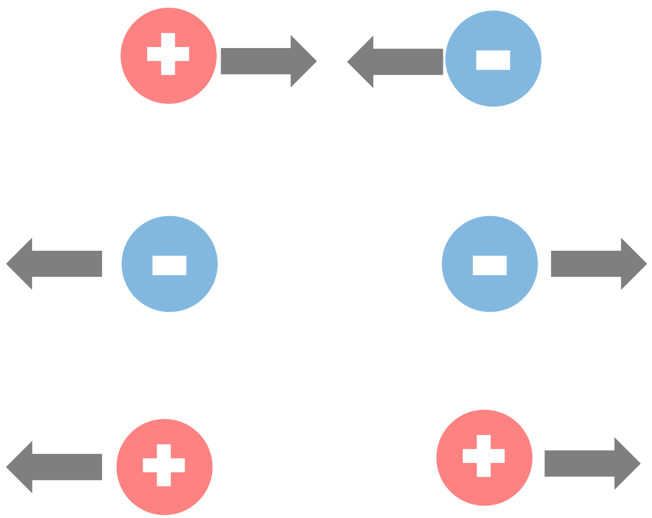
	Morning	Afternoon
Monday:	Electronics	Arduino
Tuesday:	Sensor Theory	Arduino
Wednesday:	Materials	Arduino
Thursday:	Campbell Data Loggers	

BASIC ELECTRICITY

Electric Charge

There is a physical property called **electric charge**

- Protons in the nucleus of an atom have a positive charge.
- Electrons have a negative charge.
- Their masses are vastly different but the magnitude of their charge is the same



Opposite charges attract

Like charges repel

Electric Charge

- Movement of free electrons creates electricity.

- The three building blocks that allow us to manipulate and utilize electricity:

  Voltage - the difference in charge between two points

  Current – the rate at which charge is flowing

  Resistance (impedence) - a material’s tendency to resist the flow of charge

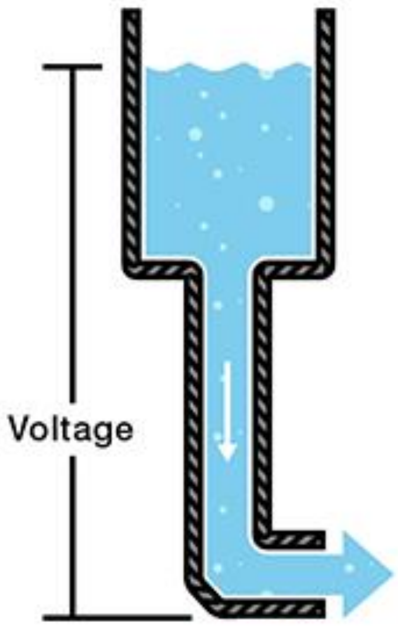
- SI unit is the Coulomb. Can also use Amp-hr.

Voltage

Voltage is the amount of potential energy between two points on a circuit

SI unit **volt** (V) is named after an Italian physicist Allesandro Volta. He invented the first chemical battery.

water = charge
water pressure = voltage
flow = current



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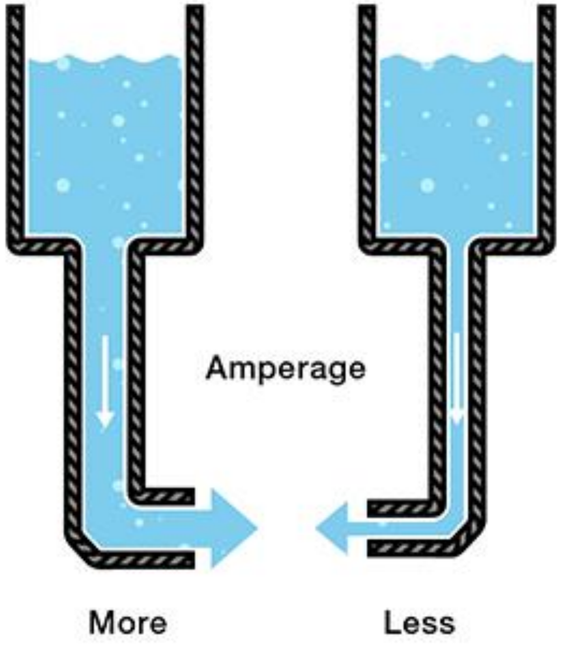
Current

Current is the amount of charge flowing through a circuit

SI unit **ampere** ("amps") is named after André-Marie Ampère, a French physicist and mathematician who founded the study of electrodynamics.



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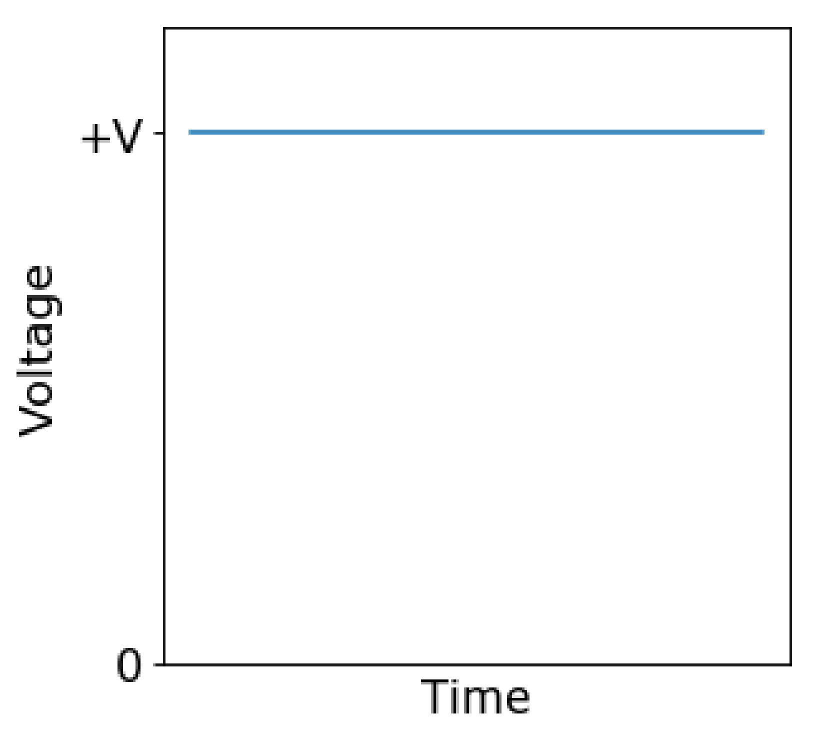
$= 1 \text{ columb (C)}$

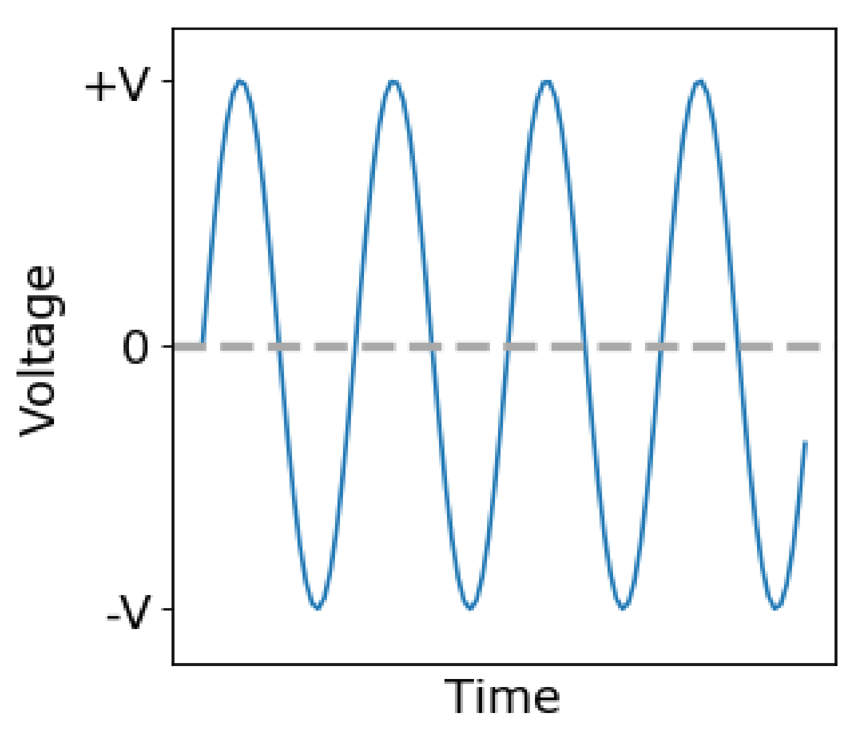
$1 \text{ amp} = \text{flow of } 1.641 \times 10^{18}$ electrons through a conductor in 1 second

$$1 \text{ A} = 1 \frac{C}{s}$$

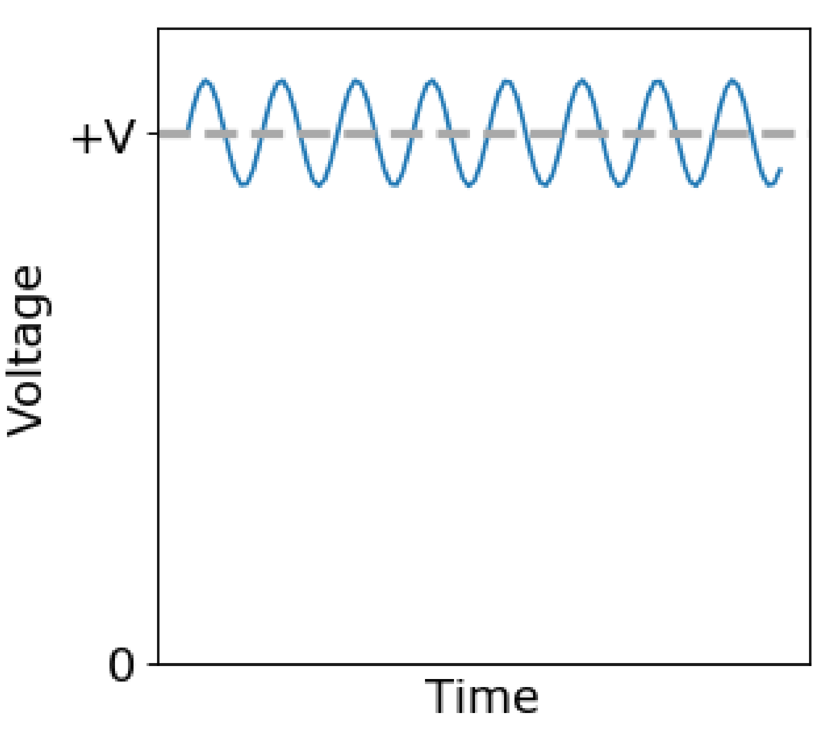
AC/DC



DC: constant voltage/
direct current



AC: alternating voltage/
alternating current

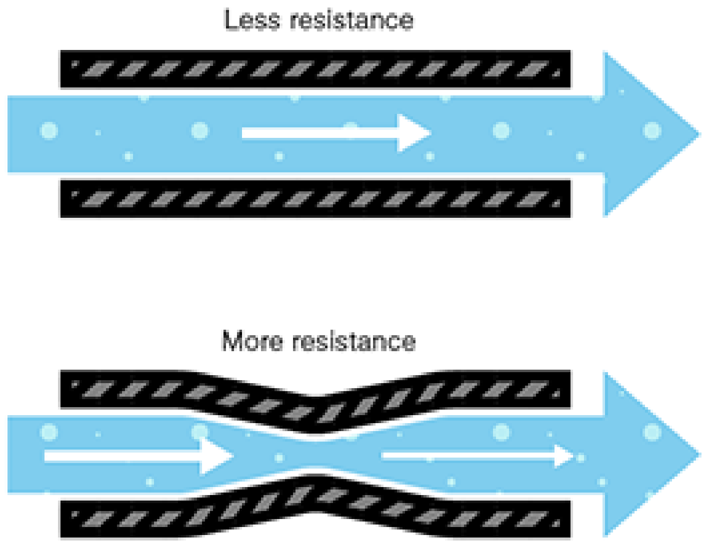


Alternating voltage added
to a constant voltage

Resistance

Resistance impedes current

SI unit **ohm** is named after Georg Ohm, a German physicist and mathematician who discovered the proportionality between voltage, current and resistance. (Ohm’s Law)



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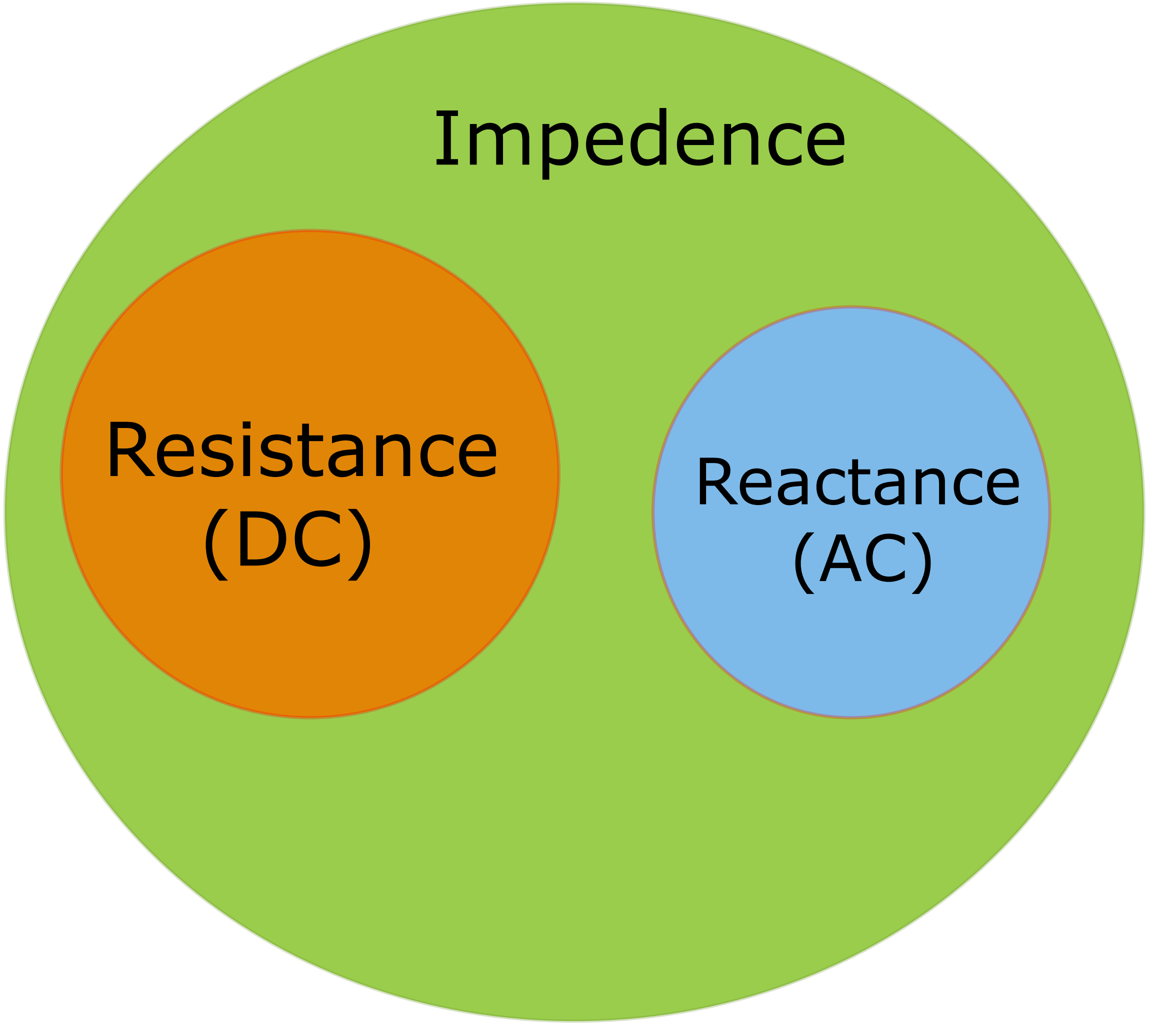
$$\frac{1V}{1A} = 1\ ohm\ (\Omega)$$

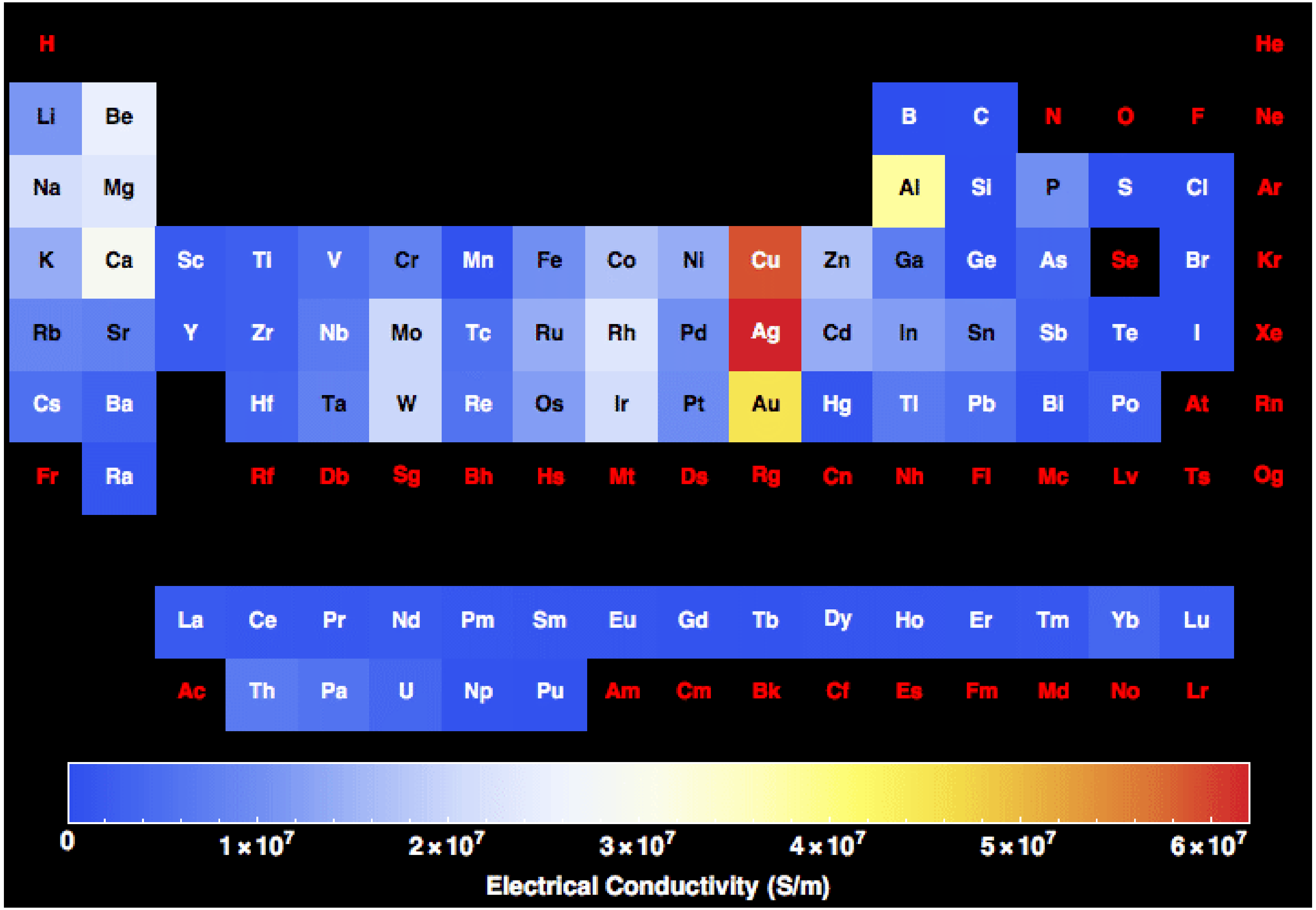
$1\text{A thru } 1\Omega\ generates\ 0.24\ calories\ of\ heat$

hose width = resistance

Resistance vs Impedence

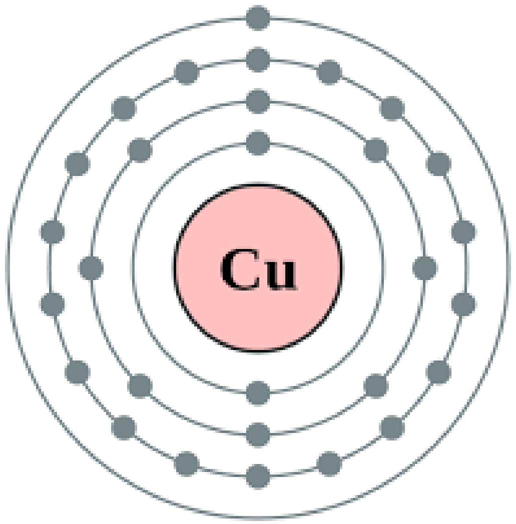


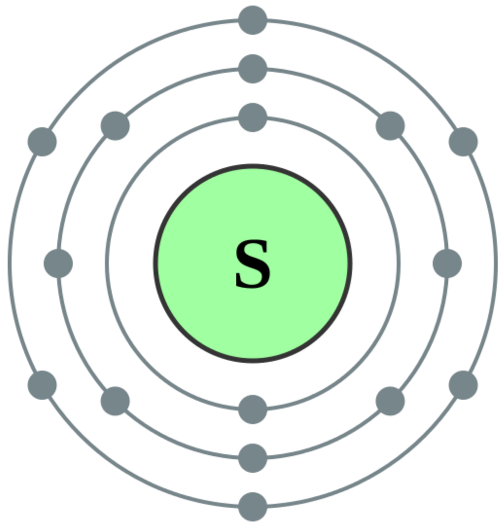
Conductivity



Conductors & Insulators

Conductors easily conduct electricity while insulators do not.





Octet Rule: The tendency of atoms to prefer eight electrons in their valance shell.

Resistivity (Ω/m) of some materials	
Carbon (graphene)	1×10^{-8}
Silver	1.59×10^{-8}
Copper	1.68×10^{-8}
Gold	2.44×10^{-8}
Calcium	3.36×10^{-8}
Zinc	5.90×10^{-8}
Lithium	9.28×10^{-8}
Iron	1.0×10^{-7}
Platinum	1.06×10^{-7}
Tin	1.09×10^{-7}
Lead	2.2×10^{-7}
Carbon (graphite)	2.5×10^{-6} to 5.0×10^{-6}
Sea water	2×10^{-1}
Drinking water	2×10^{1} to 2×10^{3}
Silicon	6.40×10^{2}
Deionized water	1.8×10^{5}
Glass	10×10^{10} to 10×10^{14}
Carbon (diamond)	1×10^{12}
Hard rubber	1×10^{13}
Sulfur	1×10^{15}
Air	1.3×10^{16} to 3.3×10^{16}
Teflon	10×10^{22} to 10×10^{24}

Less resistant

More resistant

Electrical Wire/Contacts

Pure copper is the most common. Stranded is more common than solid because stranded is more flexible

Gold is often used in connections because it resists oxidation

Aluminum is lighter than copper - often used in overhead power lines and aircraft.

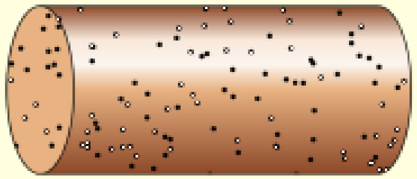
Tungsten and a nickel-chrome alloy are used in light bulbs as they can survive the high heat.

Tin also used in connections and protects exposed copper.

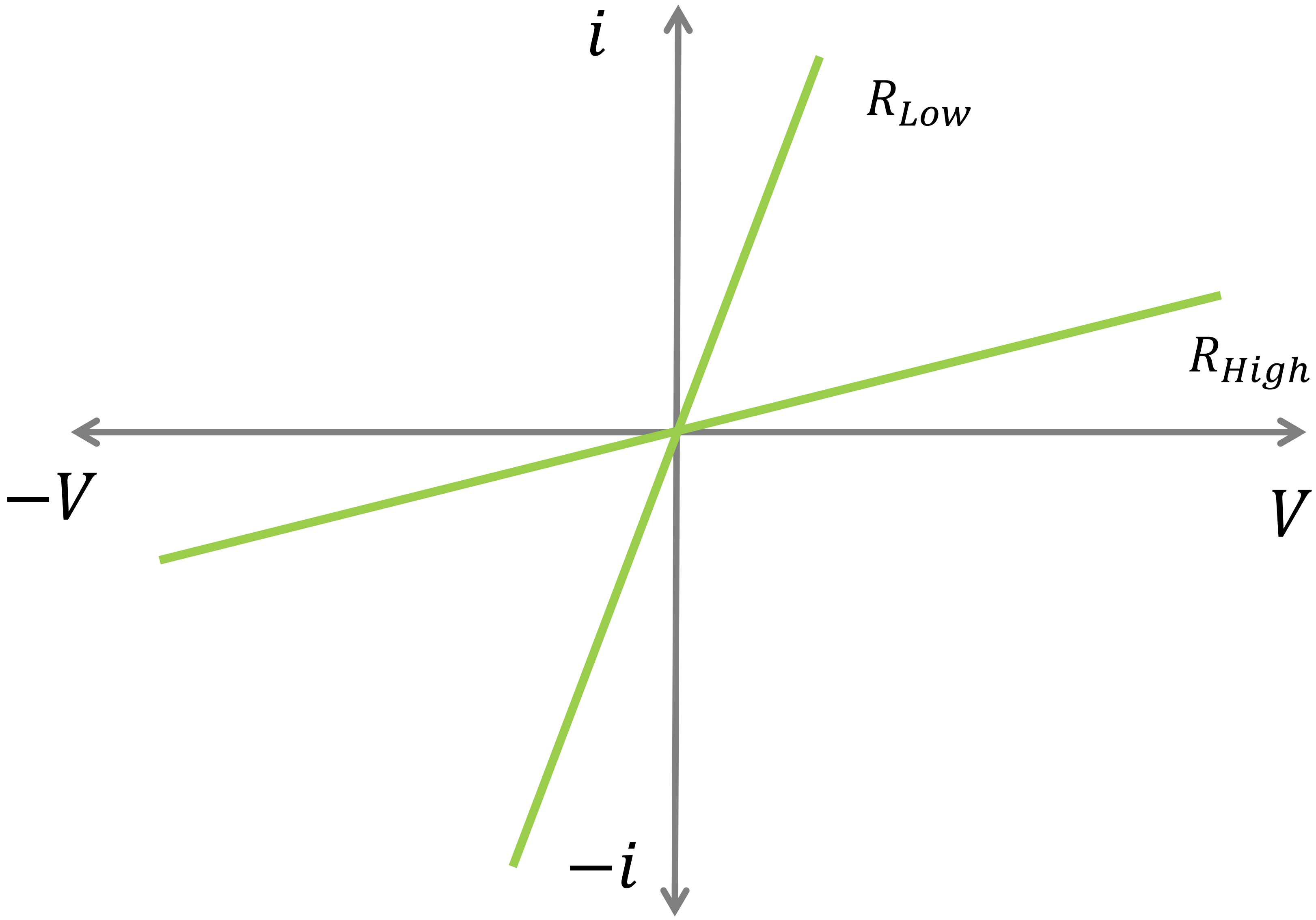
Wire by gauge

AWG	Dia. (mm)	mOhms/m	Max amps
0	8.1	0.3	200
18	1.0	21	9.5
20	0.81	34	6
22	0.64	53	5
24	0.51	84	3.5
26	0.41	134	2.2
28	0.32	213	1.4

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



Current vs. Voltage - when using resistors

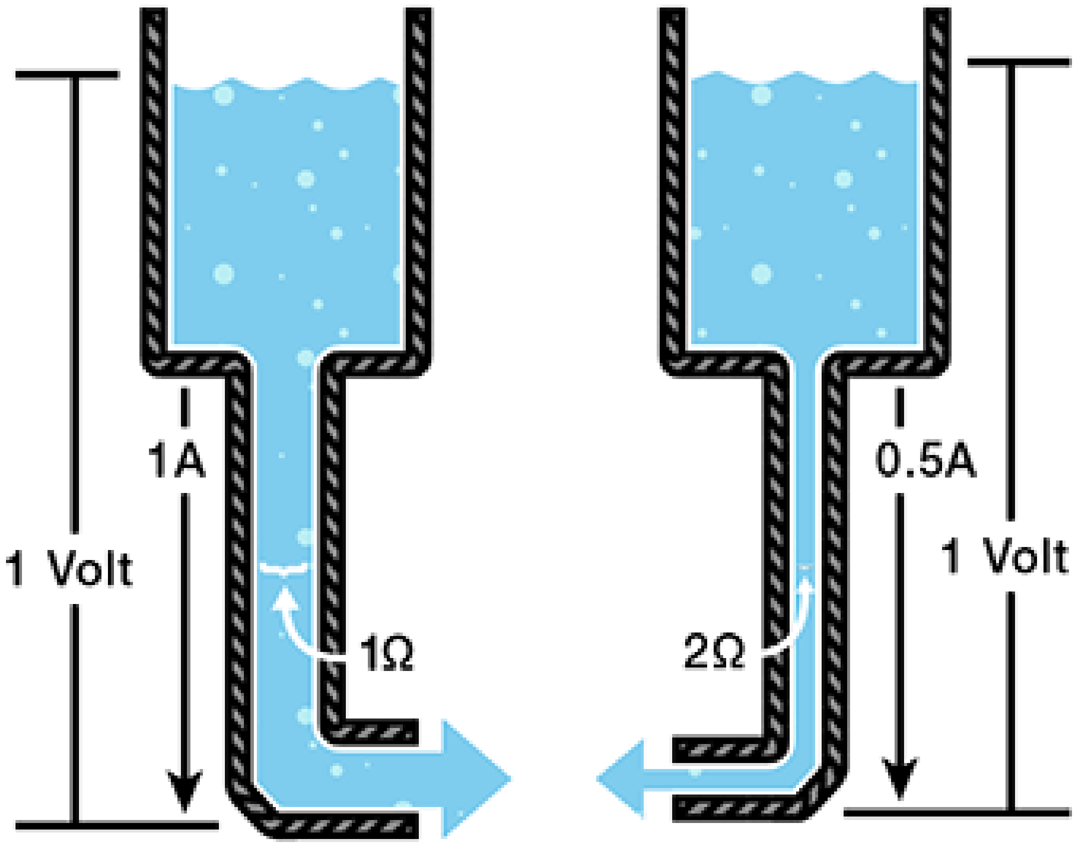


Ohm's Law

$$V = I \cdot R$$

$$1V = 1A \cdot 1\Omega$$

$$I = \frac{V}{R}$$



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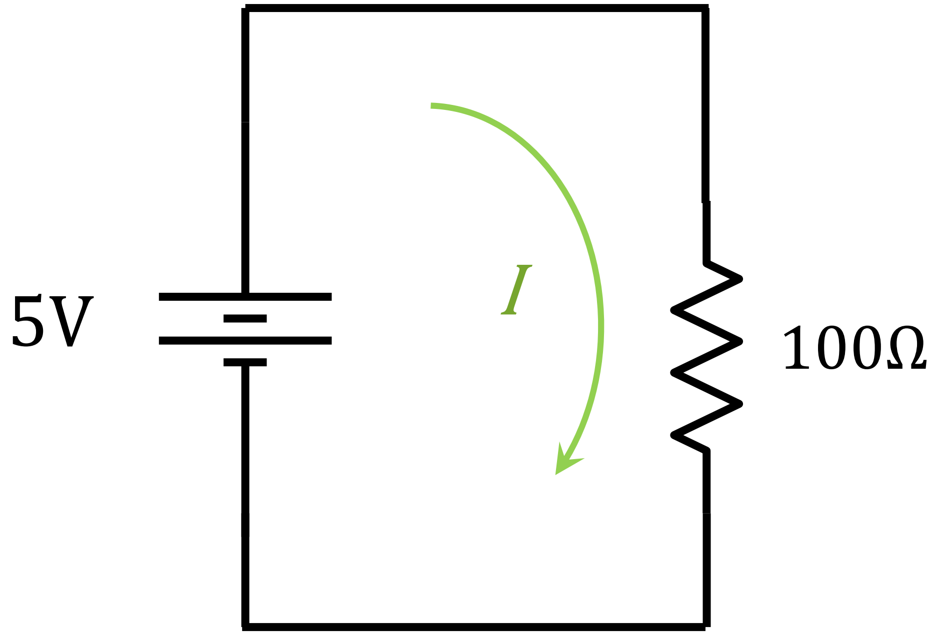
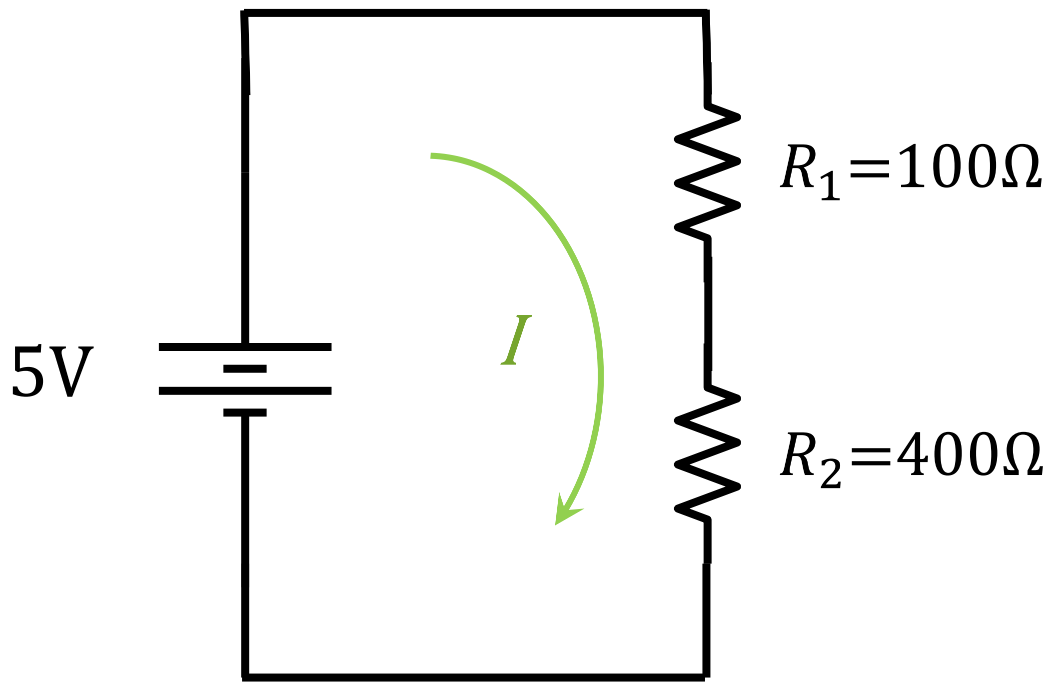
Ohm's Law

$$V = I \cdot R$$



$$I = \frac{V}{R} = \frac{5V}{100\Omega} = 0.05\text{A}$$

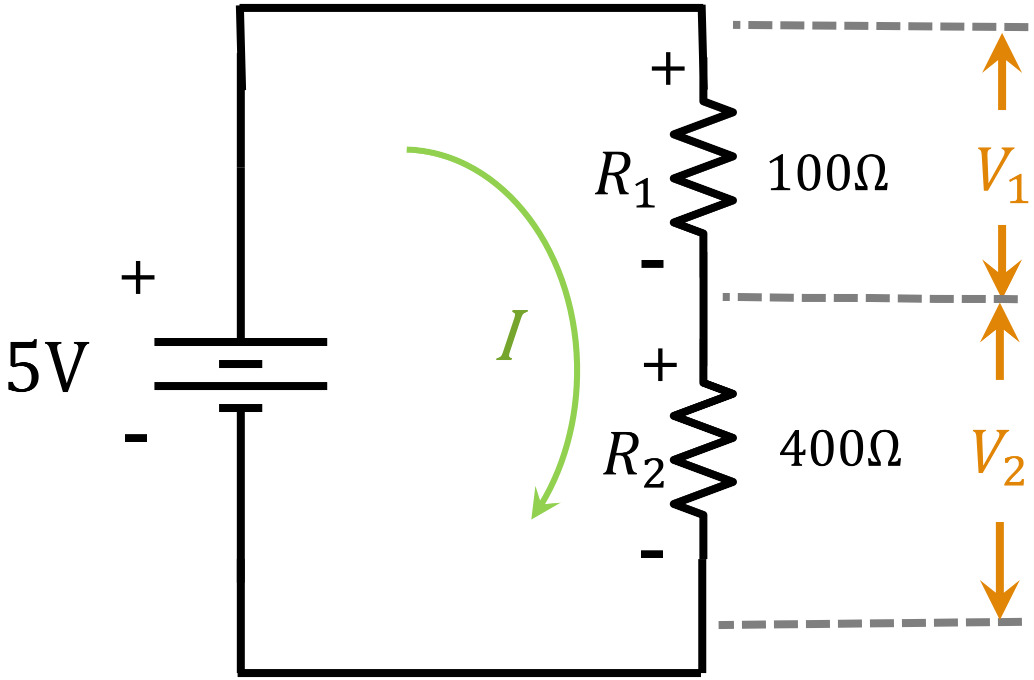
Resistors in series add



$$\mathrm{R} = R_1 + R_2 = 500\Omega$$

$$I = \frac{V}{R} = \frac{5V}{500\Omega} = 0.01\mathrm{A}$$

Kirchhoff's Voltage Law: the voltages in a circuit sum to zero



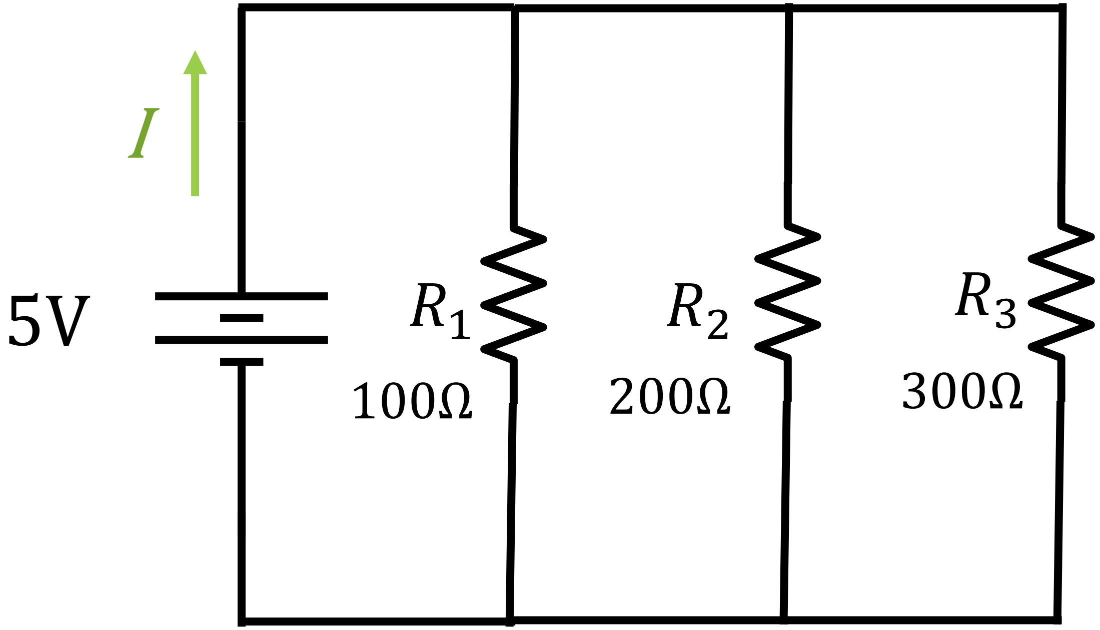
$$I = 0.01\text{A}$$

$$V_1 = 0.01\text{A} \cdot 100\Omega = 1V$$

$$V_2 = 0.01\text{A} \cdot 400\Omega = 4V$$

$$5\text{V} = 1\text{V} + 4\text{V}$$

Resistors in parallel



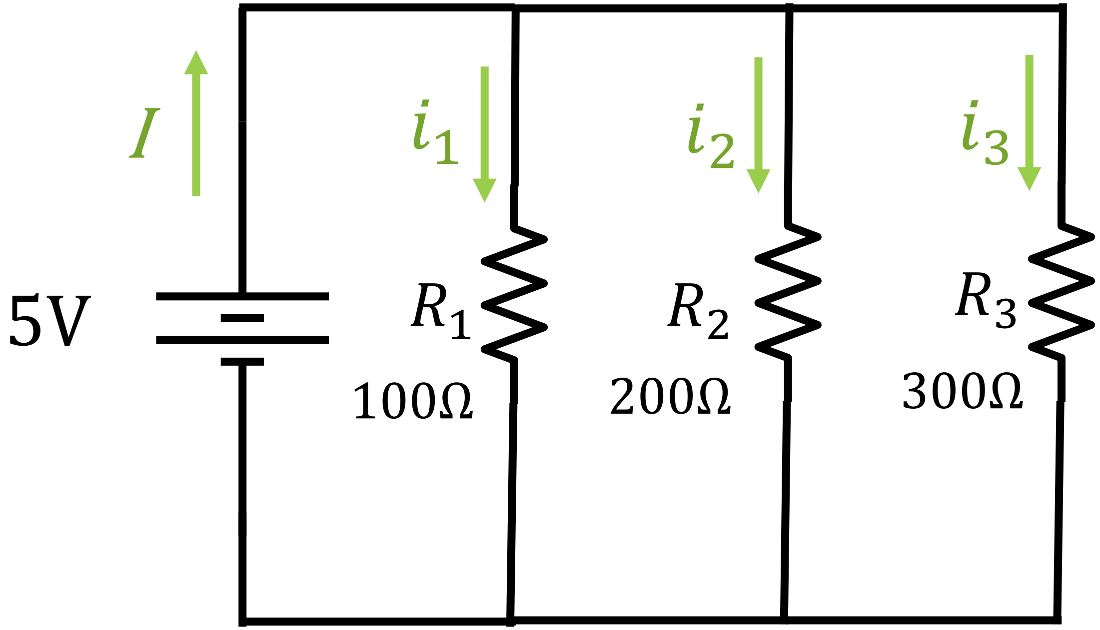
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{200} + \frac{1}{300}$$

$$\mathrm{R} \approx 54.5\Omega$$

$$I = \frac{V}{R} = \frac{5V}{54.5\Omega} \approx 92\mathrm{mA}$$

Resistors in parallel



$$I = \frac{V}{R} = \frac{5V}{54.5\Omega} \approx 92\text{mA}$$

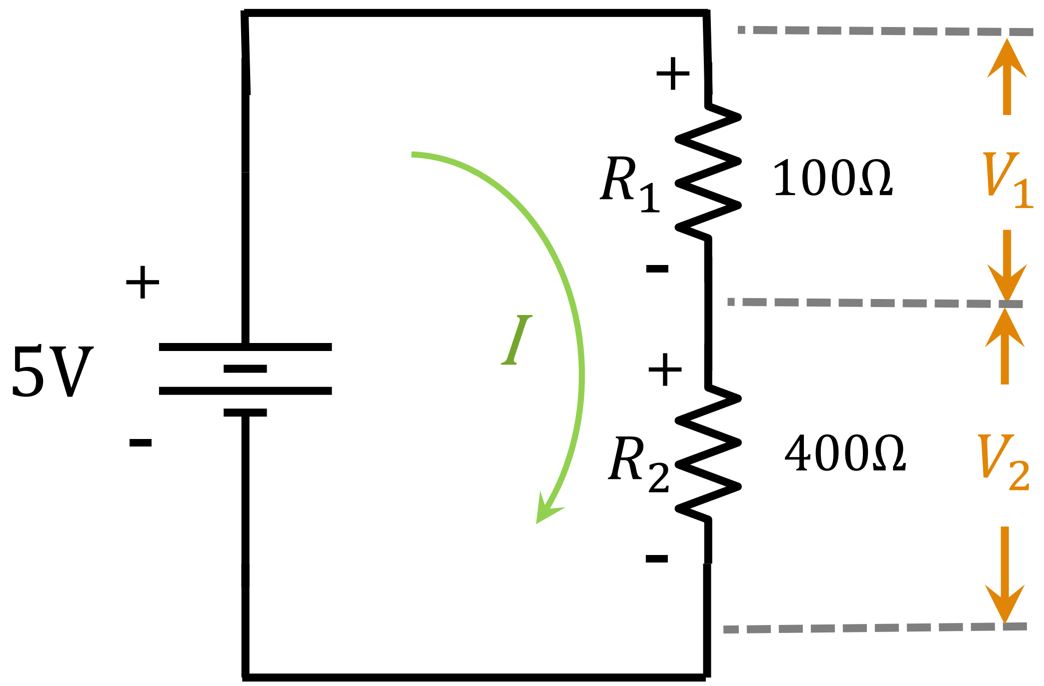
$$i_1 = \frac{5V}{100\Omega} = 50\text{mA}$$

$$i_2 = \frac{5V}{200\Omega} = 25\text{mA}$$

$$i_3 = \frac{5V}{300\Omega} \approx 17\text{mA}$$

Kirchhoff's Current Law: $i_1 + i_2 + i_3 = I$

Voltage Divider



$$I = 0.01\text{A}$$

$$V_1 = 0.01\text{A} \cdot 100\Omega = 1V$$

$$V_2 = 0.01\text{A} \cdot 400\Omega = 4V$$

$$5\text{V} = 1\text{V} + 4\text{V}$$

Open Circuit

Short Circuit

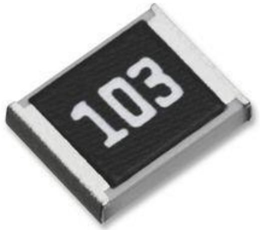
Resistors

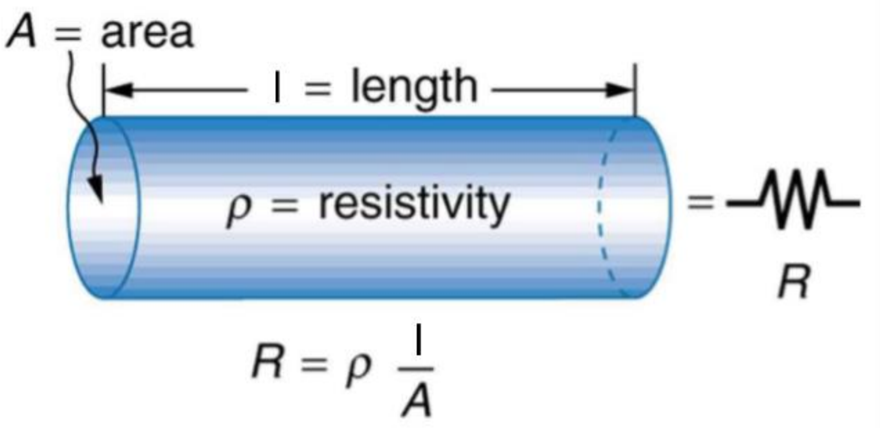
Their purpose is to reduce the current in a circuit to a desired level.

Carbon

Wirewound

Chip – surface mount



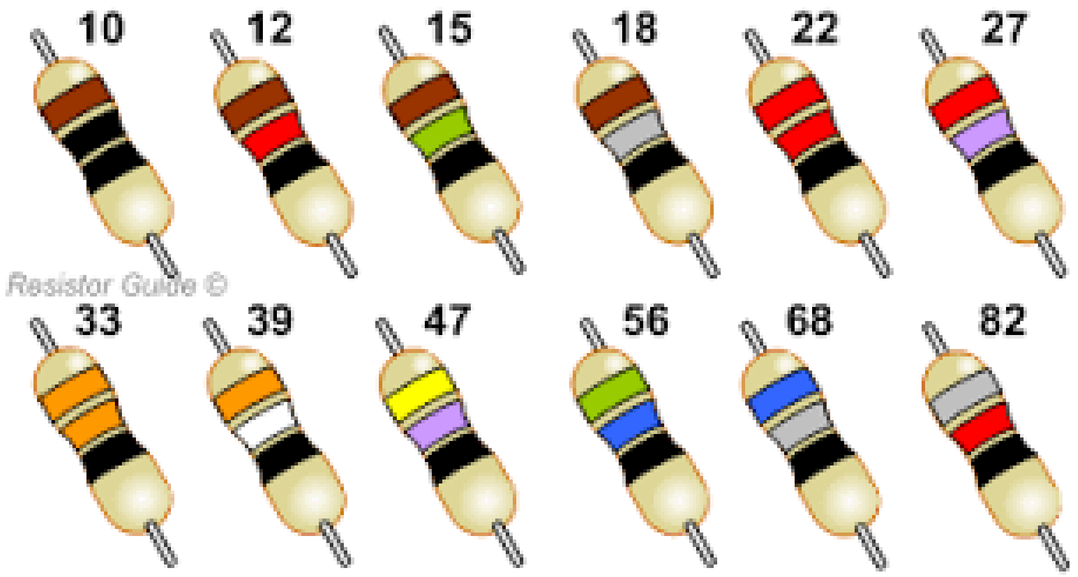


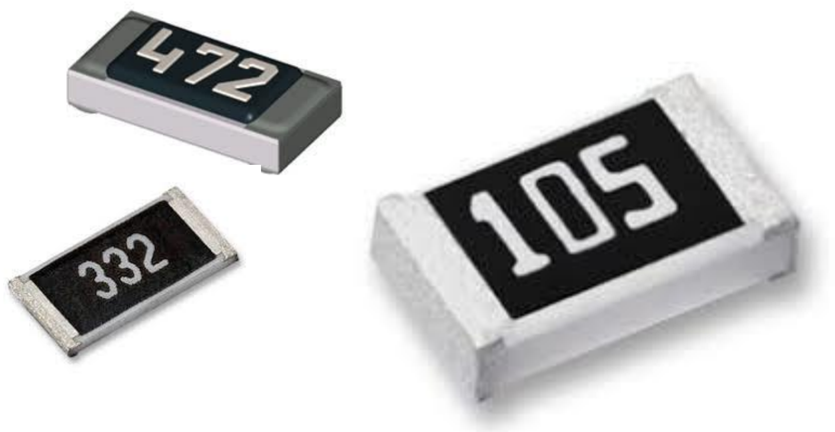
Resistors

<u>Resistance</u> – not related to physical size

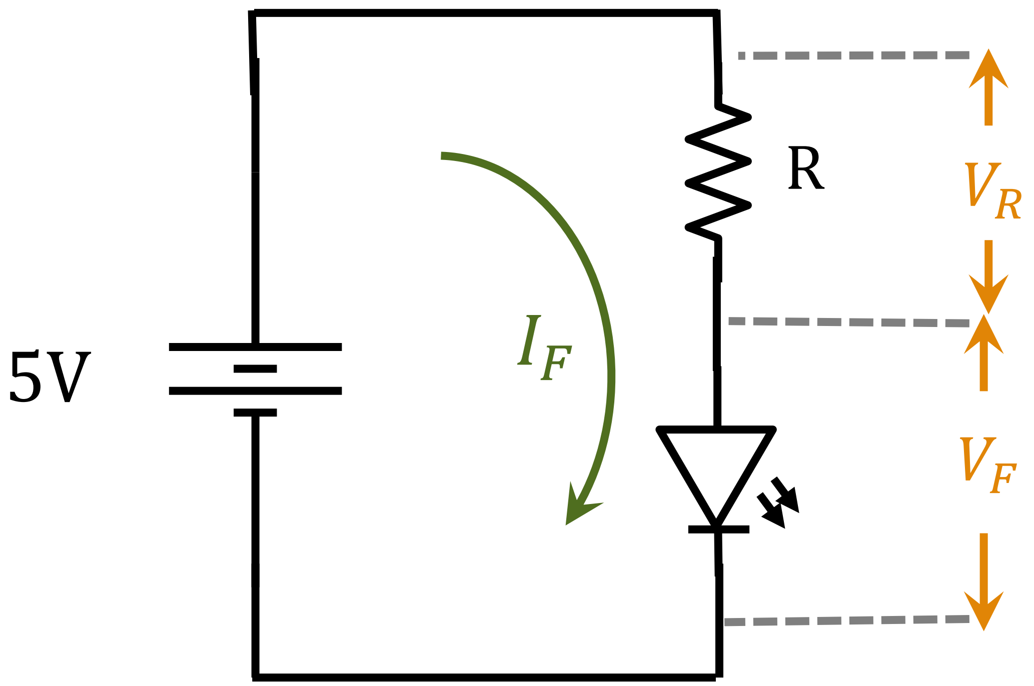
<u>Power rating</u> – related to physical size and resistance

¼ Watt is very common (e.g. 75mA @ 3.3V)





LED circuit



LED specs:

$$Forward\ voltage\ (V_F) = 1.8\ V$$

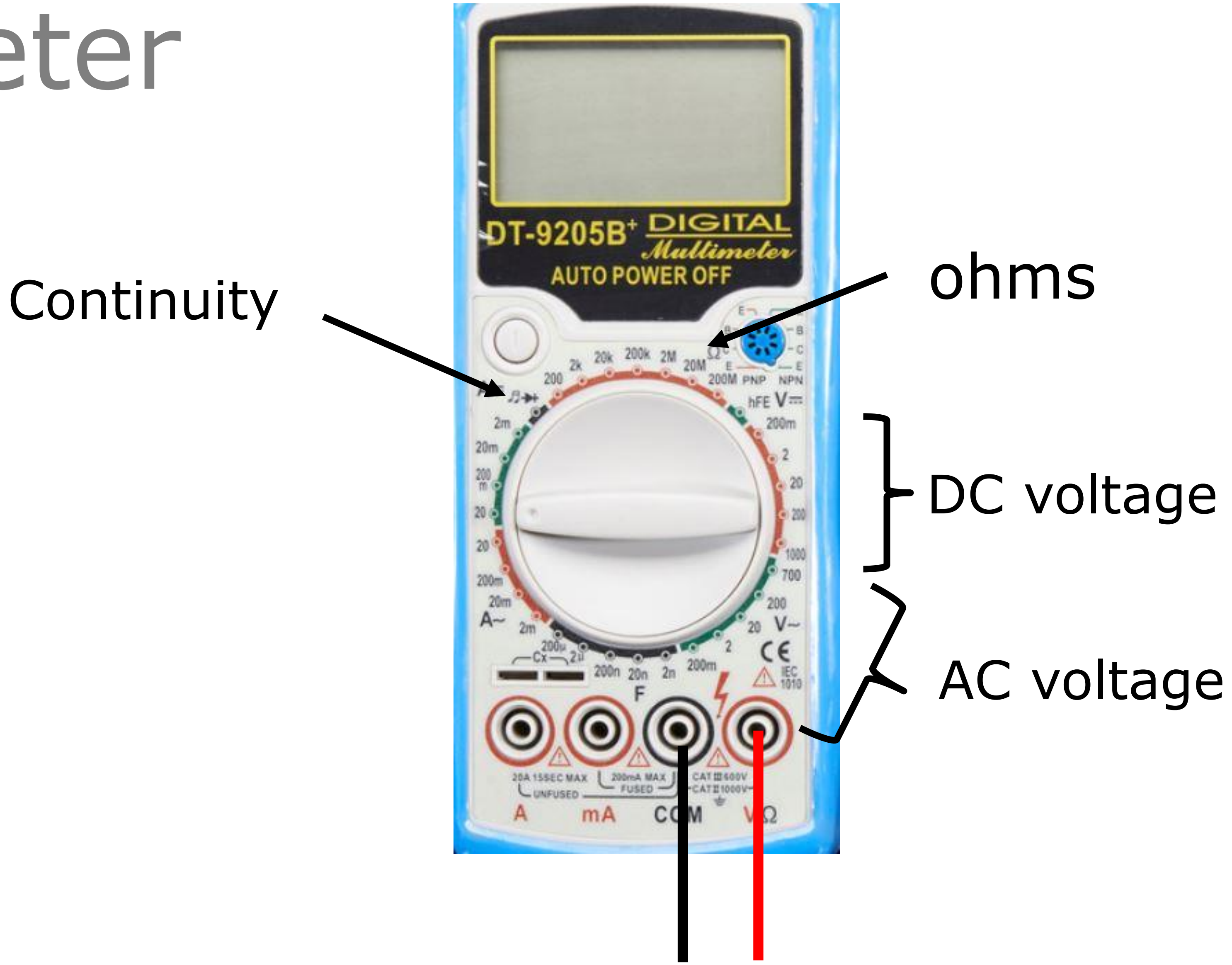
$$Forward\ current\ (I_F) = 20mA$$

From Kirchoff's voltage law:

$$V_R = 5 - 1.8 = 3.2\text{V}$$

$$R = \frac{V_R}{I_F} = \frac{3.2}{0.02} \cong 160\Omega$$

Multimeter


DT-9205B+ DIGITAL Multimeter
AUTO POWER OFF
Continuity
ohms
DC voltage
AC voltage
A
mA
COM
VΩ

Multimeter

DC current

AC current