Electricity basics

- Electric charge
- Potential difference
- Current
- Resistance
- Ohm's law
- Series circuits
- Parallel circuits
- Combination circuits - series + parallel
- Power

Electric charge

- **Charge** is a fundamental property of matter.
- We are usually talking about the movement of electrons (negative charge).
- But in electrochemical process, there is also a movement of positive charged ions.
- **1 coulomb = The charge of 6.25×10^{18} electrons.**
- One electron has a charge of 1.60×10^{-19} coulombs.

Current

- Current is the measure of how much charge is moving through a point in a time period.
- A higher current means that more charge is moving.
- **1 amp = 1 coulomb / second** (6.25×10^{18} electrons / second).
- Some scales: Nerve impulses - microamps, iPod - milliamps, toaster - amps, car engine starting - hundreds of amps, transmission lines, thousands of amps.
- A current of less than 100mA through the heart can be fatal.
- Electric current move slowly, but the electric field is nearly instant.

Low current - few electrons moving
High current - more electrons moving

Potential difference

- Separating positive & negative charge requires **work** to be done - this is a form of **potential energy**.
- A higher potential difference means that the charges carry more energy.
- This is the "push" behind electric charge. (Sometimes known as the **Electro Motive Force - EMF**)
- Measured in volts - **1 volt = 1 Joule / coulomb**

$$\text{Potential difference} = \frac{\text{Energy}}{\text{Charge}}$$

Potential differences can be positive or negative - relative to the Earth at 0V.

Resistance

- Resistance is the measure of amount potential difference needs to be pushing to get an amp of current.
- Higher resistance: higher potential difference needed or lower current.
- 1 ohm = 1 volt / amp.
- We can consider a whole electric circuit to be the equivalent of one resistor.
- Adding resistors in series increases resistance.
- Adding resistors in parallel reduces resistance.

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

A 2500 Ω resistor (each colour indicates one of the numbers)

Ohm's law

Current can be increased in a circuit by:

- **Increasing the potential difference** pushes more electrons through.
- **Decreasing the resistance** to allow more electrons through.
- For example, a brighter globe has a lower resistance than a dim one.

$$\text{Current} = \frac{\text{Potential difference}}{\text{Resistance}} \qquad I = \frac{V}{R}$$

An **ohmic** resistor has a constant resistance over a wide range of potential differences.

Series circuits

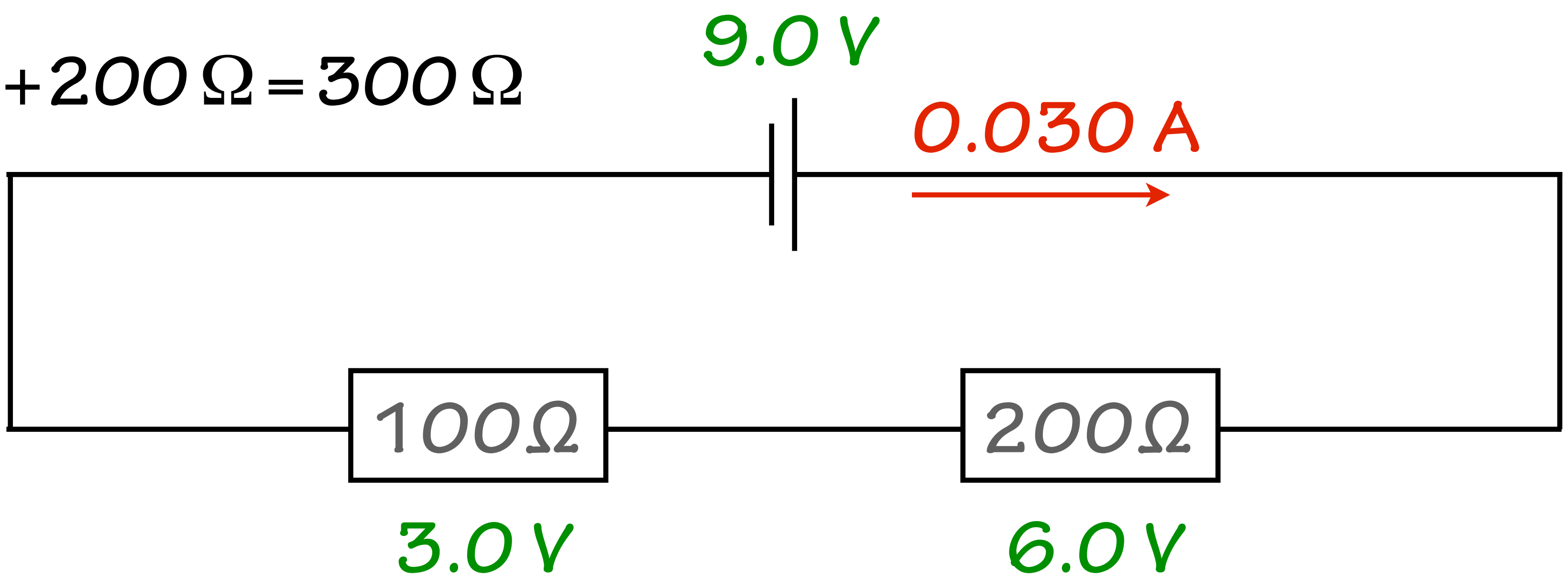
- The current through a series circuit is the same at all points.
- Around the whole circuit, the sum of the potential differences is zero.

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

$$R = 100\,\Omega + 200\,\Omega = 300\,\Omega$$

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

$$I = \frac{9.0\,V}{300\,\Omega} = 0.030\,A$$



$$V = IR$$

$$V = 0.030\,A \times 100\,\Omega$$

$$V = 3.0\,V$$

$$V = 0.030\,A \times 200\,\Omega$$

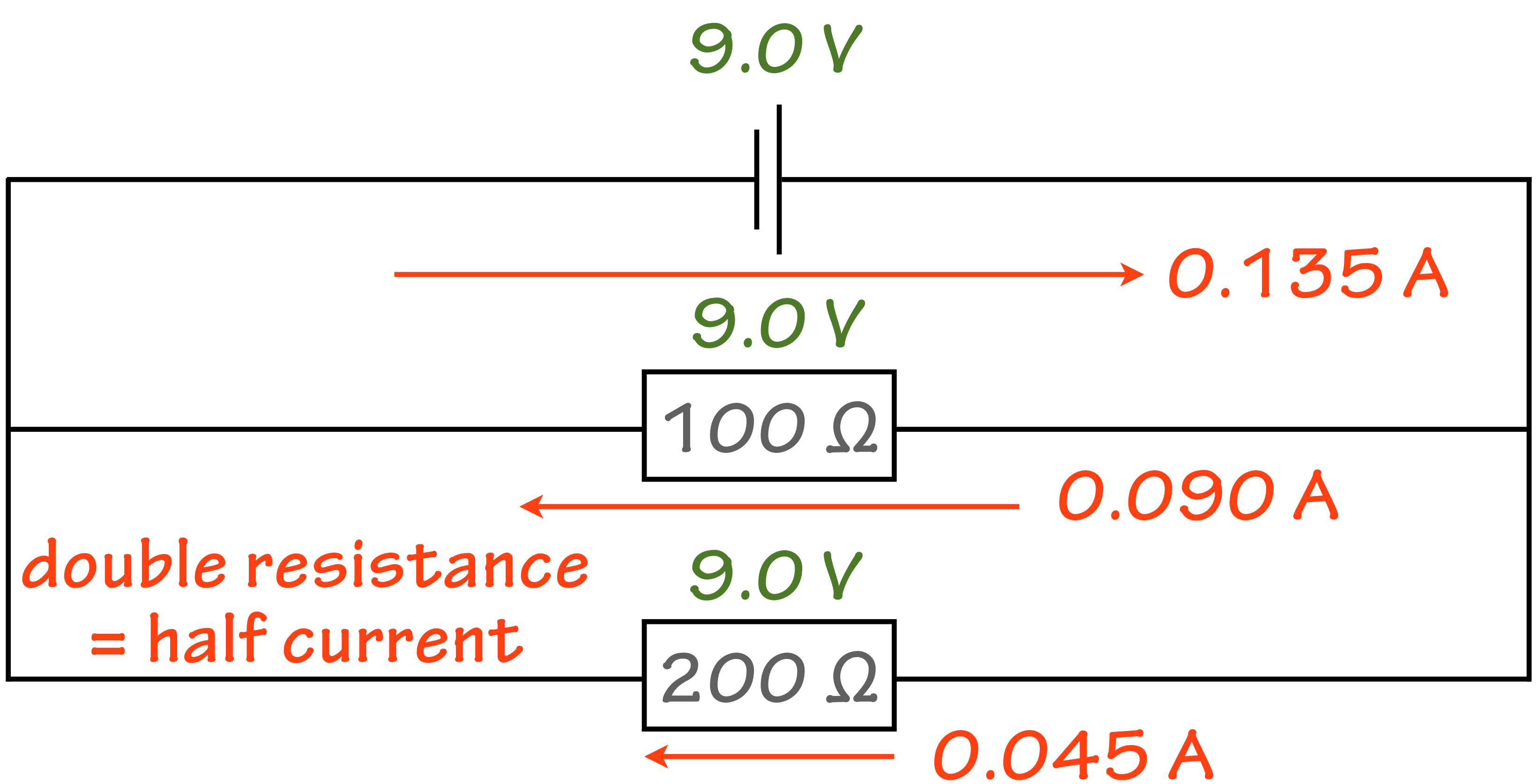
$$V = 6.0\,V$$

This is also known as a **voltage divider** - the fraction of voltage is the as the fraction of resistance.

Parallel circuits

- The potential difference across two or more parallel components is the same.
- At any junction in the circuit, the sum of the currents in is equal to the sum of the currents out.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \frac{1}{R} = \frac{1}{100\,\Omega} + \frac{1}{200\,\Omega} \qquad \frac{1}{R} = \frac{3}{200\,\Omega} \qquad R = 67\,\Omega$$



$$I = \frac{9.0\,V}{67\,\Omega} = 0.135\,A$$

$$I = \frac{9.0\,V}{100\,\Omega} = 0.090\,A$$

$$I = \frac{9.0\,V}{200\,\Omega} = 0.045\,A$$

Combination circuits - series + parallel

1. Find the total resistance.
2. Find the total current.
3. Use I = V/R or resistance ratios for currents.
4. Use V = IR or voltage divider rule for voltages.

Parallel resistors

$$\frac{1}{R} = \frac{1}{100\,\Omega} + \frac{1}{200\,\Omega}$$

$$R = 67\,\Omega$$

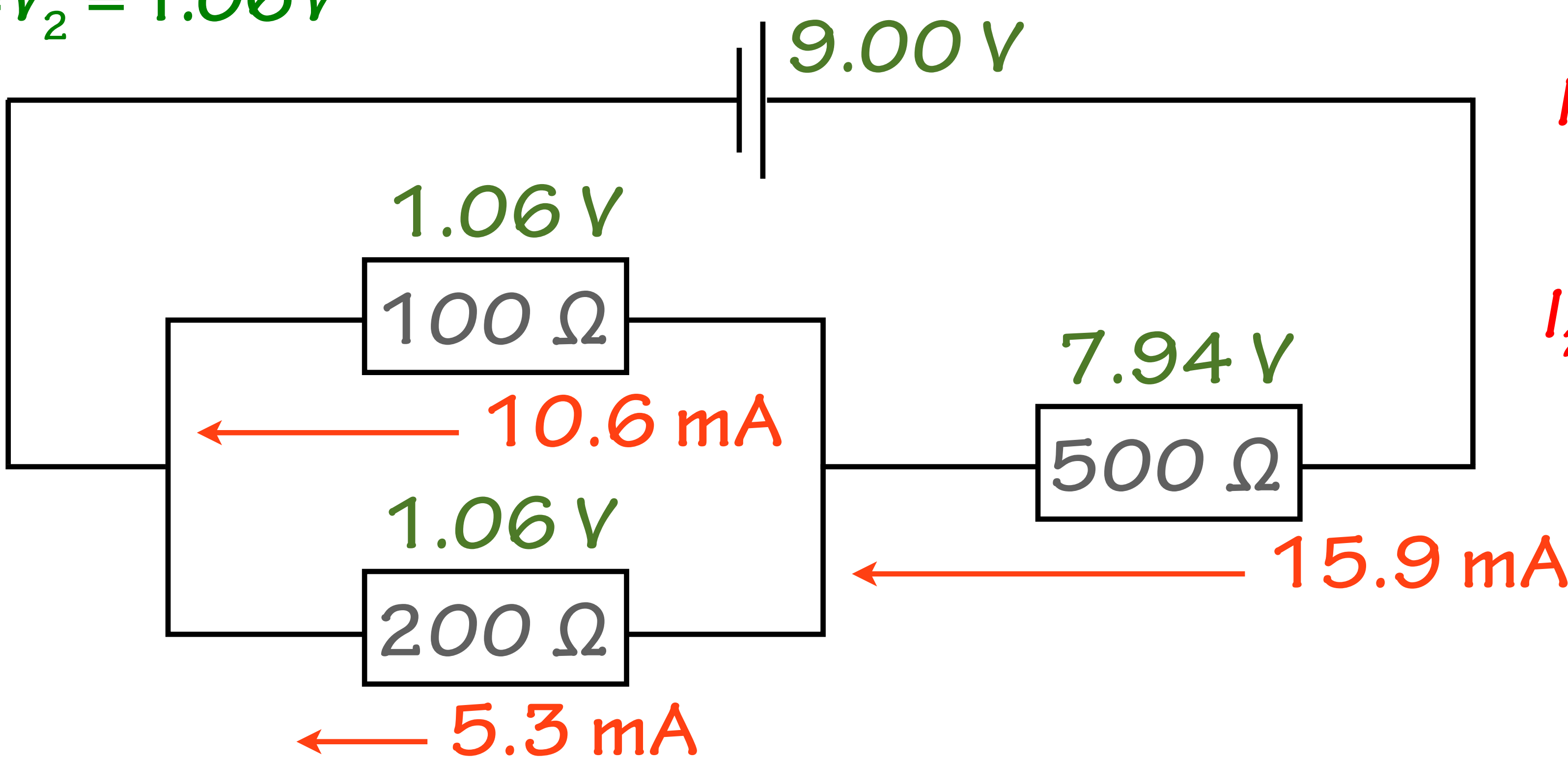
Total resistance

$$R = 500\,\Omega + 67\,\Omega = 567\,\Omega$$

$$V_1 = 0.0159\,A \times 500\,\Omega = 7.94\,V$$

$$V_2 = 9.00\,V \times \left(\frac{67\,\Omega}{567\,\Omega}\right) = 1.06\,V$$

$$V_3 = V_2 = 1.06\,V$$



$$I_1 = \frac{9.00\,V}{567\,\Omega} = 0.0159\,A$$

$$I_2 = \frac{V_2}{R_2} = \frac{1.06\,V}{100\,\Omega} = 0.0106\,A$$

$$I_3 = \frac{1}{3} \times 15.9\,mA = 5.3\,mA$$

Power

- Power is the measure of how much energy is dissipated through a device in a time period.
- 1 Watt = 1 Joule / second.

$$\frac{\text{Charge}}{\text{Time}} \times \frac{\text{Energy}}{\text{Charge}} = \frac{\text{Energy}}{\text{Time}}$$

$$P = \frac{E}{t} \longrightarrow E = Pt$$

$$P = IV$$

Power (Watts)

Current (amps)

Potential difference (volts)

Some scales: torch light - watts, heater - kilowatts, electric generator - gigawatts.

Power calculations

- eg a light globe that draws a current of 200 mA at 240 V.
- P = IV = 0.2A x 240V = 48 W = 0.048 kW
- Energy = Power x time = 0.048 kW x 24 hours
- In 24 hours, the total energy used is 1.15 kWh.
- This is the same as using 1.15 kW for 1 hour.
- Electricity is billed at around 25c per kWh.
- This would cost : 25c x 1.15 = 29 cents / day.

$$1\,kWh = 1000\ J/s \times 3600\ s = 3.6\ MJ$$