# Basic electricity

Dr Peter Lawson

| Quantity | Unit | Symbol |
|---|---|---|
| **voltage** | volt | V |
| **current** | ampere | A |
| **resistance** | ohm | Ω |
| **power** | watt | W |
| **frequency** | hertz | Hz |
| **capacitance** | farad | F |
| | | |

| | | | |
|---|---|---|---|
| giga | ×1,000,000,000 | (G) | GHz |
| mega | ×1,000,000 | (M) | MHz, MΩ |
| kilo | ×1,000 | (k) | kHz, kΩ, kV |
| milli | ×0.001 | (m) | mV, mA, mW |
| micro | ×0.000 001 | (μ) | μV, μA, μW, μF |
| nano | ×0.000 000 001 | (n) | nF |
| pico | ×0.000 000 000 001 | (p) | pF |

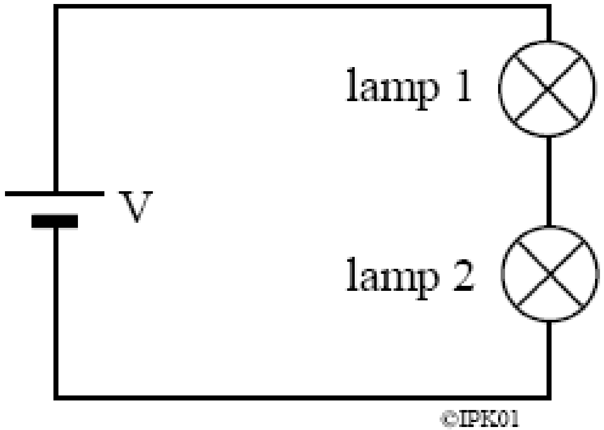



Figure 3.1

There are essentially two ways in which electronic components can be arranged in a circuit, in **series** or **parallel**. A simple series circuit is shown in figure 3.1, consisting of a cell (battery) and two lamps.

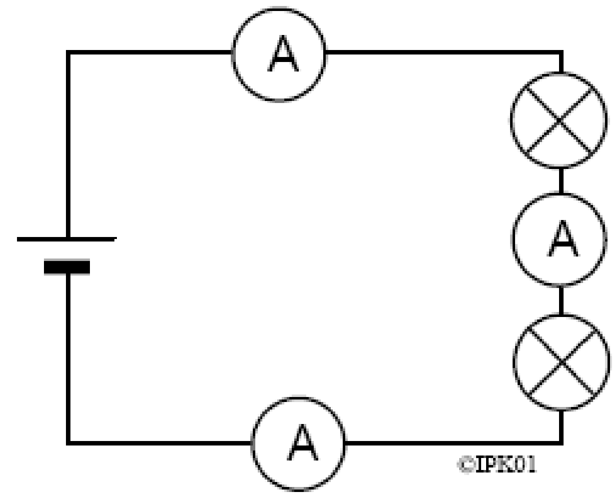



Figure 3.2

As electrons pass around a circuit, they lose energy, but the electrons are **not** *"used up"* in any way. (Indeed, if they were, then the whole circuit would become radioactive!!) This means that in a series circuit the current will be the same wherever it is measured.

If three ammeters were placed in the series circuit as shown in figure 3.2, they would all have the same reading.

The same argument can also be applied to currents entering and leaving a junction in a circuit. Figure 3.3 shows a junction in a circuit. Since electrons cannot suddenly appear or disappear, the current shown on the ammeter must equal the sum of the other currents.
The ammeter therefore reads

$$\mathbf{3A + 2.2A - 1.5A = 3.7A}$$

with the current flowing away from the junction.

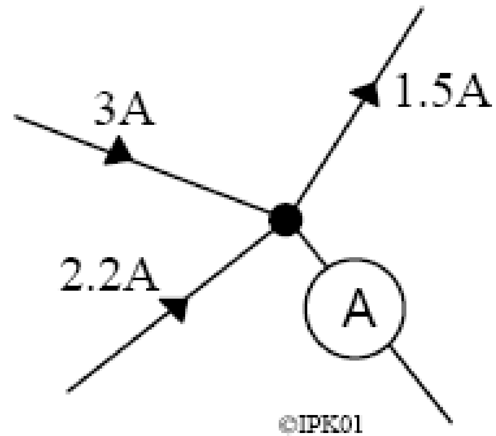


Figure 3.3

# Analogy

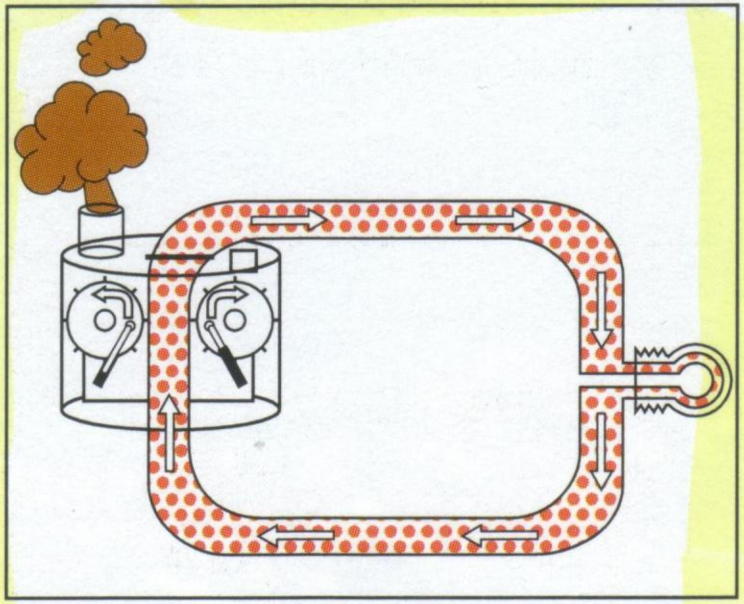


*Figure 1.3 A mechanical analogy – the engine pushes the balls around the 'circuit'*

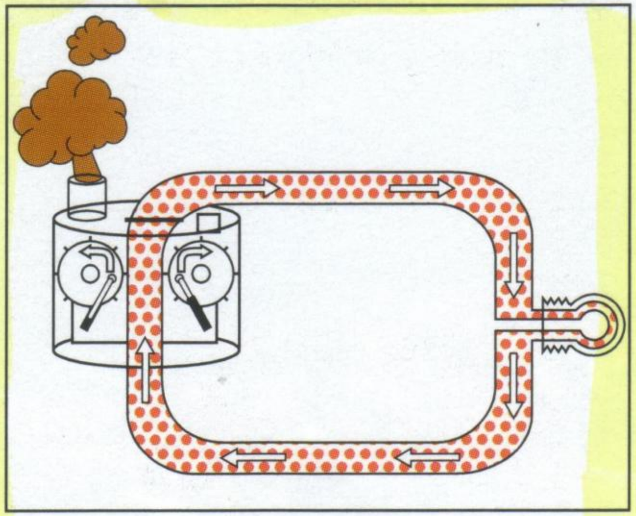


*Figure 1.3* **A mechanical analogy – the engine pushes the balls around the 'circuit'**

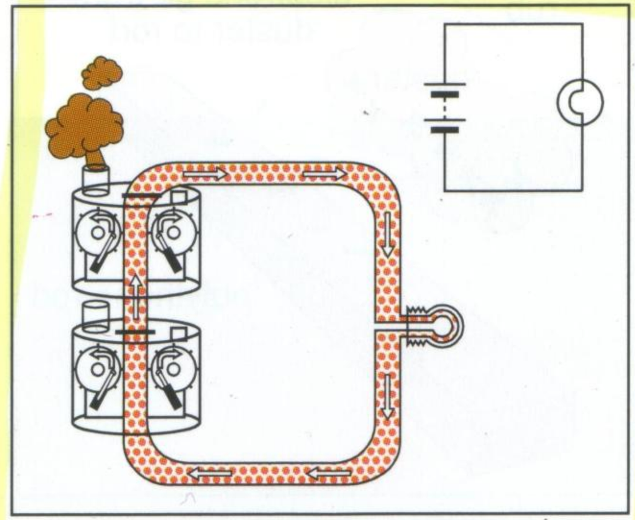


*Figure 1.6* **With two cells (engines), the electrons (balls) move faster**

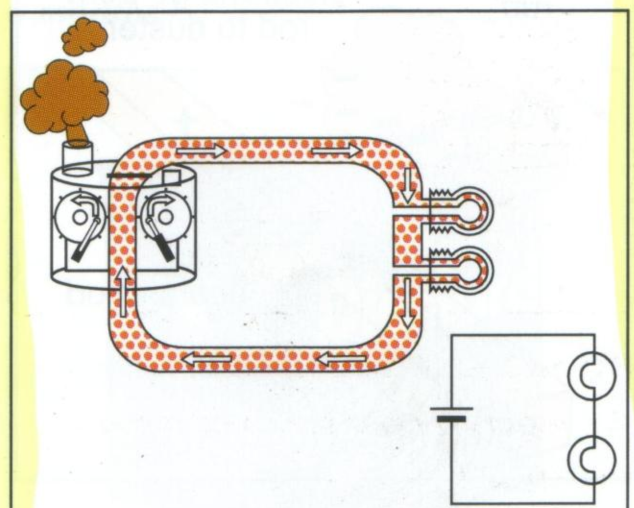


*Figure 1.7* **Both lamps resist the current, so the flow is less**

Electrons cannot give out any more energy in a circuit than they are initially supplied with by the power supply or battery. In a simple series circuit this means that the sum of the voltages across all of the components is equal to the voltage of the power supply. In figure 3.1 this means that

**voltage across lamp 1 + voltage across lamp 2 = voltage of battery, V.**

The only common circuit in which lamps are arranged in series is Christmas tree lights. There are usually twenty lamps connected together in series. Each lamp is rated at 12V and so the whole series circuit can be connected to the mains electricity supply of 240V (230V).

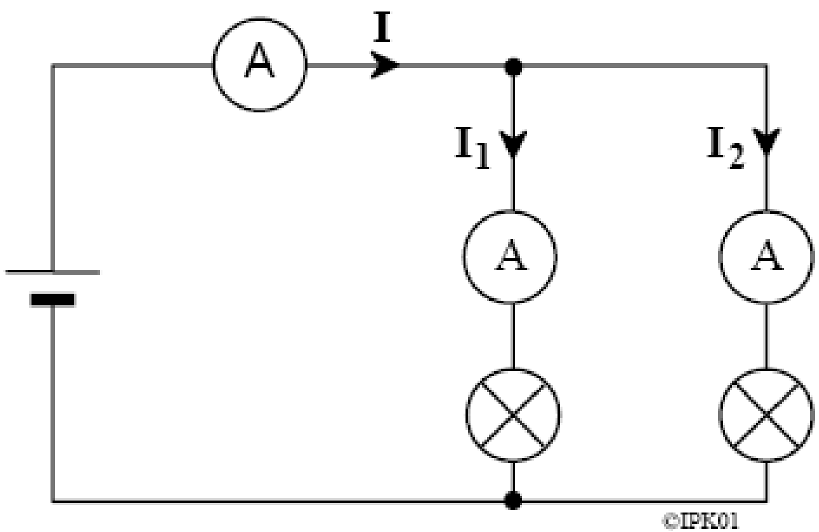



Figure 3.4

A simple parallel circuit is shown in figure 3.4. As can be seen, each lamp is connected directly (through an ammeter) to the battery, and so the voltage across each lamp is the same as the battery voltage.

The current, however, is split at each junction. This means that

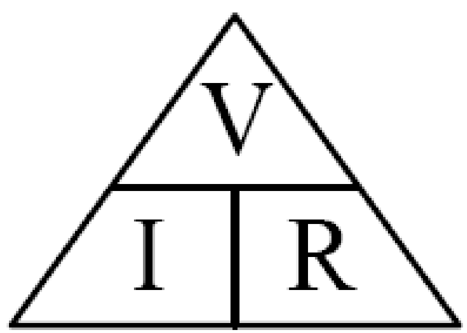
$$\mathbf{I = I_1 + I_2}$$

## Ohm's Law

Electrons move more easily through some materials than others when a voltage is applied across the material. The opposition to current flow is called **resistance** and is measured in **ohms (Ω)**. Larger units are *kilohm*, ($k\Omega = 10^3\ \Omega$) and *megohm*, ($M\Omega = 10^6\ \Omega$.)

Resistance is defined as follows.

$$\mathbf{resis\,tan\,ce = \frac{voltage}{current} = \frac{V}{I}}$$



## Resistors In Parallel

When two resistors, eg. $R_1$ and $R_2$, are connected in parallel, as in figure 3.6,

- the voltage across each resistor is the same, **V**,
- the total current, **I**, is equal to the sum of the currents in the separate resistors,

$$\mathbf{I = I_1 + I_2}$$

- the resulting resistance, **R**, is given by:-

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

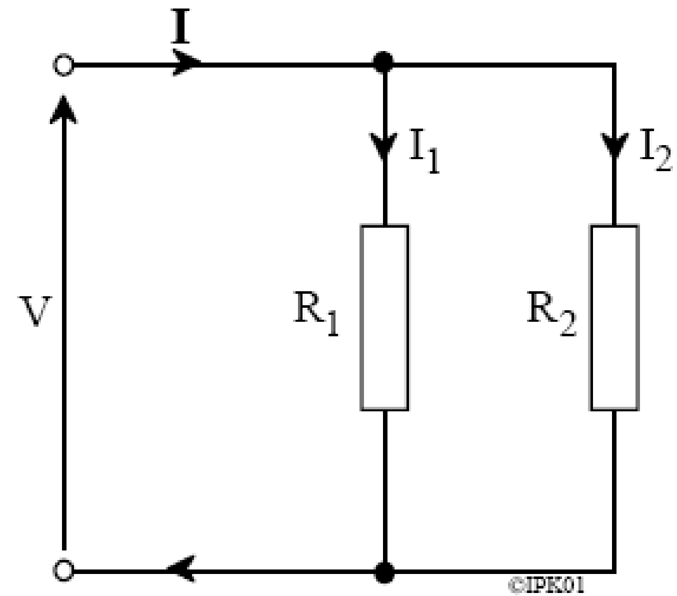
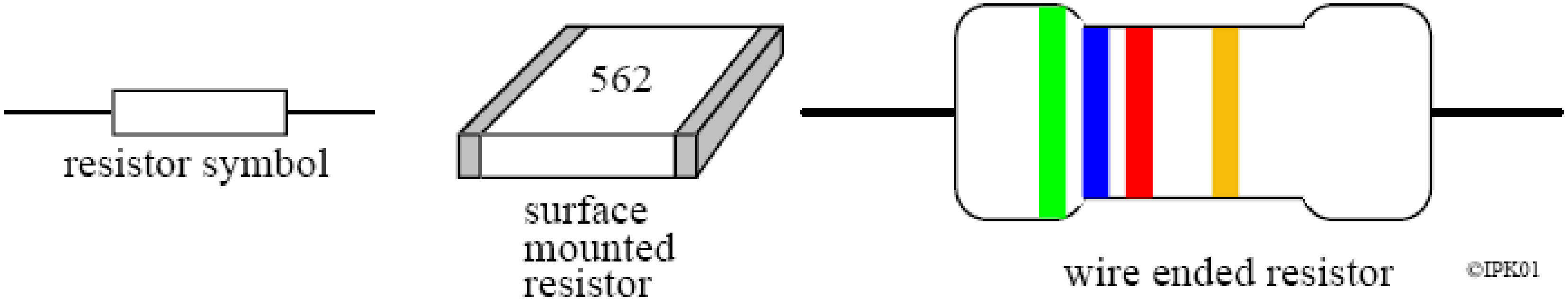



Figure 3.6.

component outlines



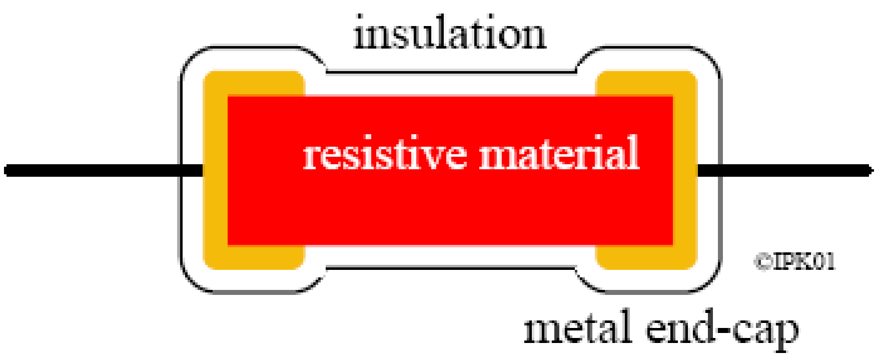


Figure 3.9

A resistor consists of two metal end caps with a resistive material placed in between as shown in the cross-sectional diagram in figure 3.9.

There are three common substances used for the resistive material. These are Carbon, Metal Oxide and Thin Wire.

**Carbon resistors** are cheap but they tend to be unstable (their resistance changes with temperature and time) and can produce unwanted noise in circuits.
**Metal oxide resistors** are more expensive but are more accurate (smaller tolerance), more stable and produce much less electrical noise.
**Wire wound resistors** are the most expensive but can be very stable and accurate. They can often be designed to dissipate large amounts of power. However, because they are made from a coil of fine wire they are of little use in radio circuits since they have appreciable inductance.

## Preferred Values

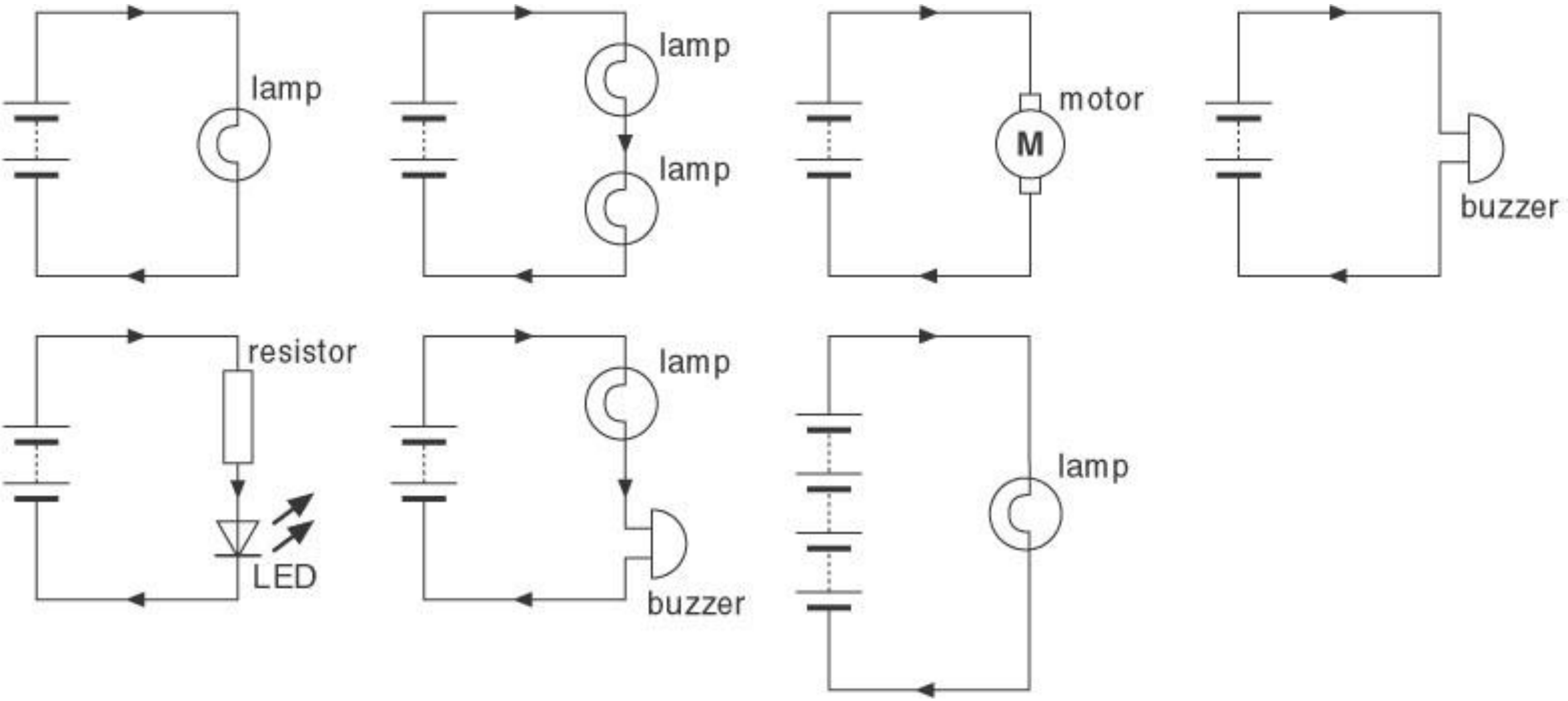
Since exact values of fixed resistors are unnecessary in most circuits, only certain *preferred* values are made. The values chosen for the E24 series (with ± 5% tolerance ) are as follows.

**1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1,** and multiples that are powers of ten greater.

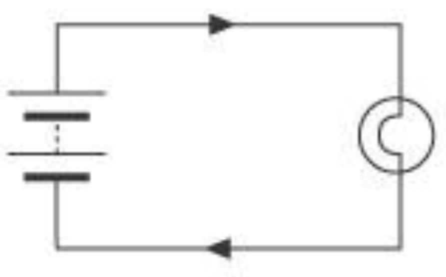
# TASK

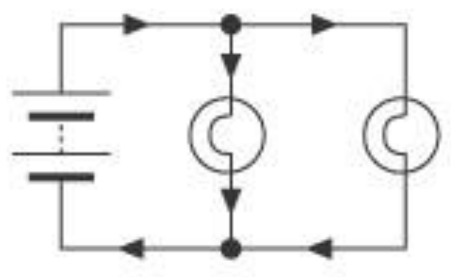
Build and test the following circuits.
Can you calculate first?
Remember Current measured in series with Ammeter
Voltage measured in parallel with voltmeter

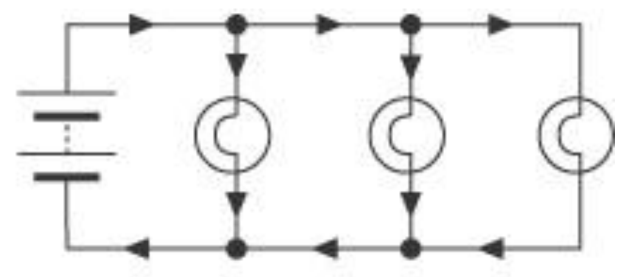
# Series circuits

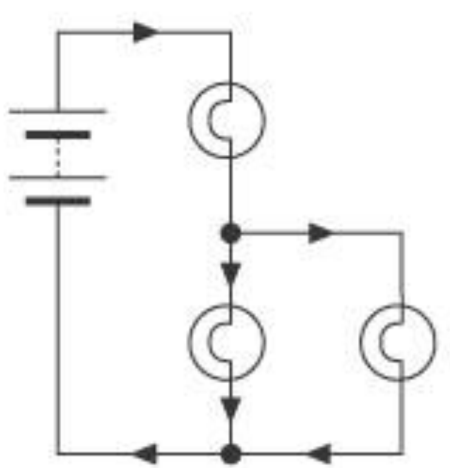


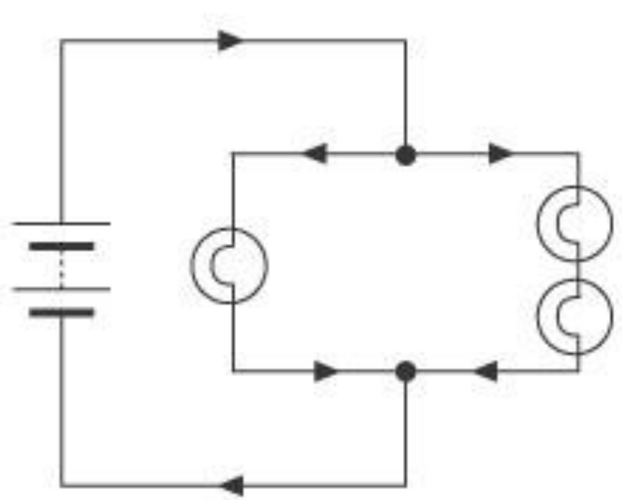
# Parallel Circuits



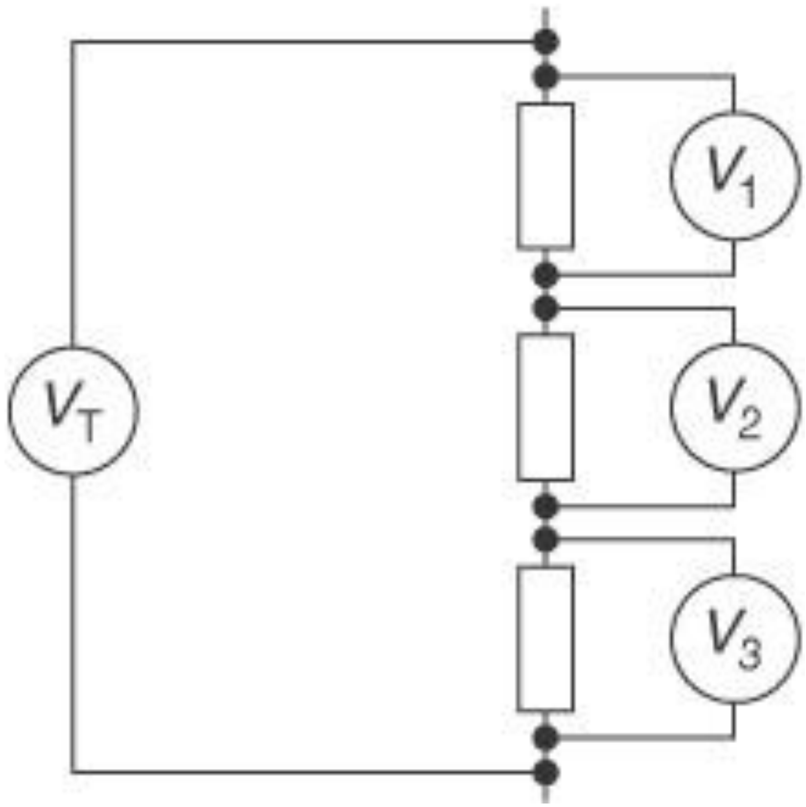








# Potential divider

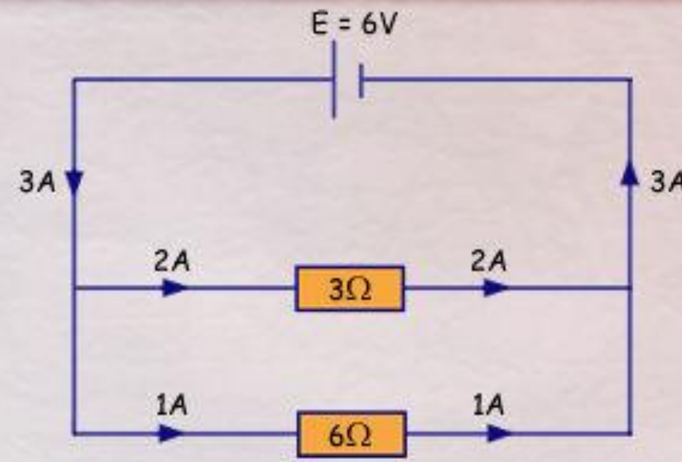



Test all around circuit for Voltages and currents

# Kirchoff's Laws

## First Law

In a circuit, total charge is conserved; no charge is lost or gained as current flows. As a result the current in a circuit is constant. This is Kirchoff's first law which states that the total current entering a junction is the same as the current leaving a junction.

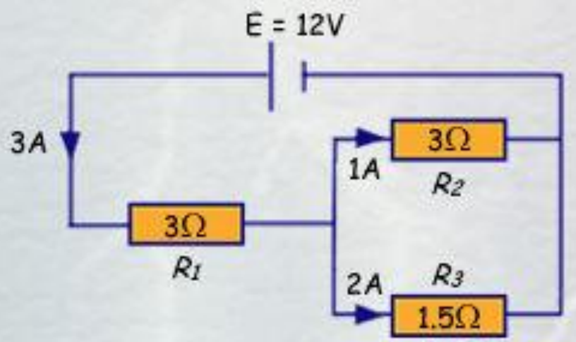



The current splits up as it flows into the parallel branches of the circuit, but recombines to produce the same total current as it leaves the parallel branches.

## Second law

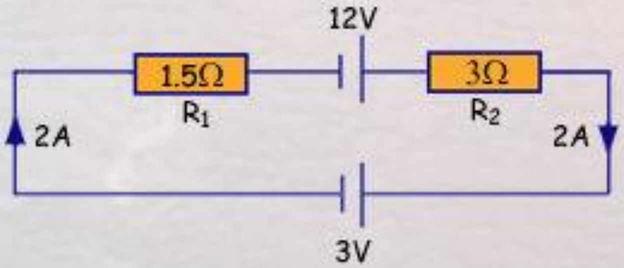
The electron charges forming a current are supplied with electrical energy as they pass through the battery. This electrical energy is transferred to other forms of energy as it flows through the circuit. Kirchoff's second law states that in any closed circuit loop the algebraic sum of the emfs equals the algebraic sum of the pds.

It follows from Kirchoff's second law that the branch circuit loops of a parallel circuit all have the same potential difference. In the first law diagram both branches have the same potential difference of 6V.




For resistor $R_1$ the pd across it is given by $V = IR_1 = 3 \times 3 = 9V$
For resistor $R_2$ the pd across it is given by $V = IR_2 = 1 \times 3 = 3V$
For resistor $R_3$ the pd across it is given by $V = IR_3 = 2 \times 1.5 = 3V$
There are two closed branch circuit loops one with resistors $R_1$ and $R_2$ and the other with resistors $R_1$ and $R_3$. In both cases the algebraic sum of the pds (12V) equals the algebraic sum of the emf.

The fact that the sum of the potential differences is algebraic means that the direction of the potential difference is accounted for by Kirchoff's second law.




In the circuit the algebraic sum of the emfs = 12 + (-3) = 9V
therefore $V = IR_1 + IR_2 = (2 \times 1.5) + (2 \times 3) = 9V$

summary