

Chapter 2: Sensors and Electricity

Charge **Unit: Coulomb, C** **Symbol: Q**

Electrons, ions protons all carry charge. We know these particles have a charge as they attract and repel each other. It is hard to explain exactly what charge is. It is the interaction of photons, a property of particles. The charge of one electron is $-1.6 \times 10^{-19} \text{ C}$.

Current **Unit: Ampere, Amp, A** **Symbol: I**

Current is the rate of flow of charge (coulombs), with respect to time. We can write this:

$$I = Q / t$$

Charges flow because charges have been separated (in a battery, for example), which then attract or repel each other's charges. Separating the charges needs energy. This stored energy is then dissipated or transformed when a current flows between positive and negative terminals.

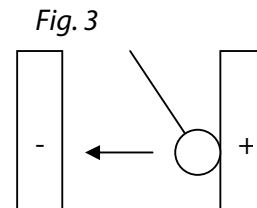
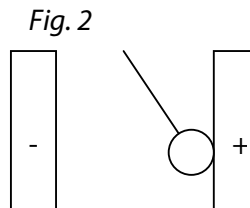
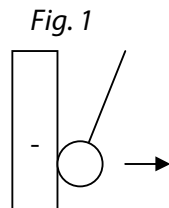
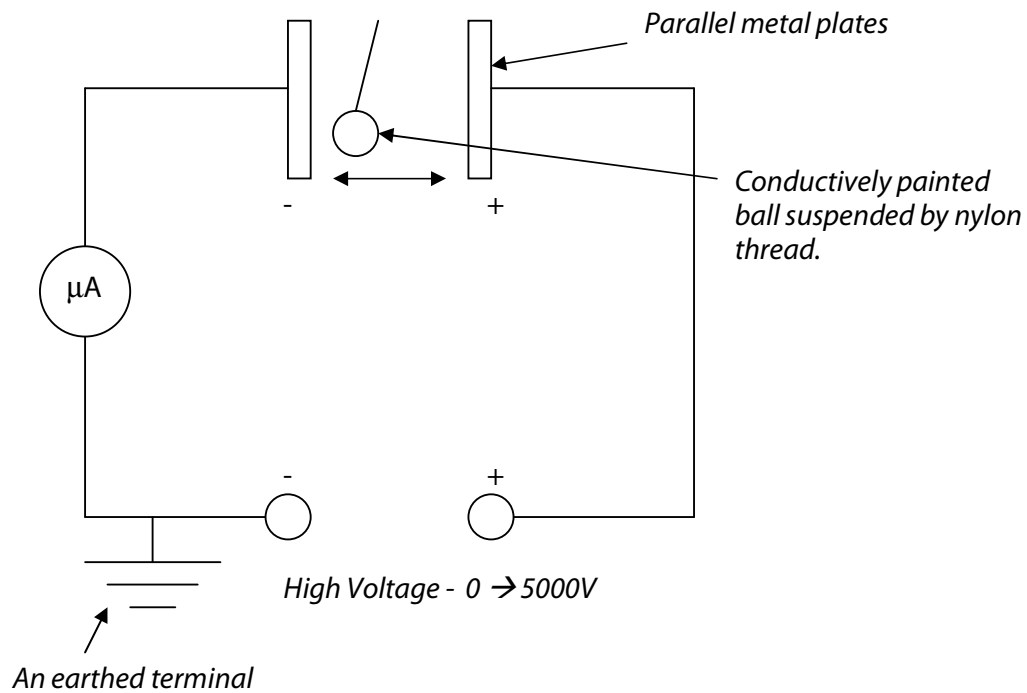


Fig 1. The neutral ball is touched on the negative plate. It becomes negatively charged as electrons move from the plate to the surface of the ball. This makes the plate repel the ball.

Fig 2. The negatively charged ball is attracted toward the positively charged plate.

Fig 3. When the ball touches the plate the electrons move from the ball to the positively charged plate. This causes the ball to become positively charged. It is then repelled from the positive plate, and attracted to the negative plate.

This process is repeated and the ball swings between the two plates. The overall effect is the flow of electrons from the negative plate to the positive plate.

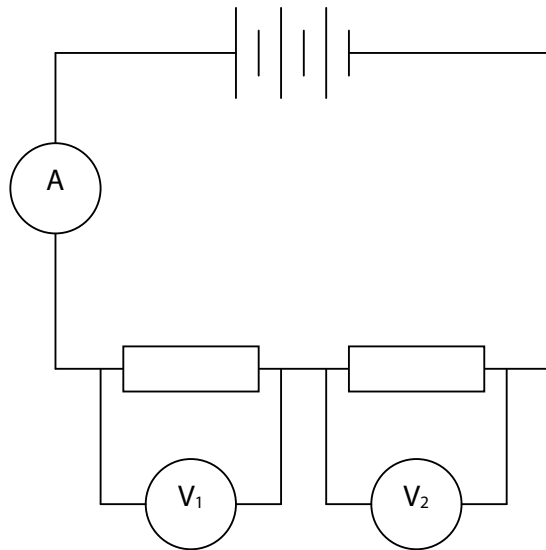
Voltage **Unit: Volts, V** **Symbol: V**

A voltmeter measured the difference between energy in coulombs flowing in and coulombs flowing out. Potential difference is the energy that is converted per coulomb of charge that flows. Potential difference, is measured in Joules per coulomb, Volts.

In a circuit the same current and charge flows through each bulb. The coulombs of charge are converting more energy (into light etc) in the bright bulb than in the dim one. The energy converted by each coulomb is measured by the potential difference across each bulb.

Potential difference is therefore measured by (*where $E = \text{Energy}$*):

$$V = E / Q$$



The sum of the voltages on the two voltmeters, V_1 and V_2 equals the total voltage supplied to the circuit.

Power **Unit: Js^{-1} , Watts, W** **Symbol: P**

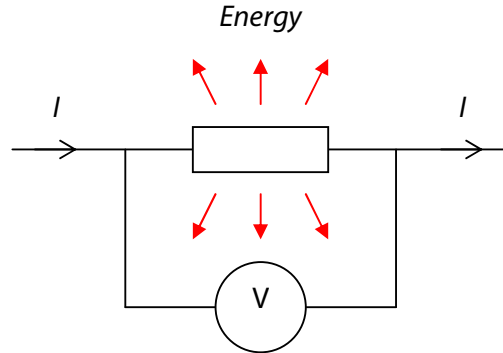
Power is the rate of change of energy with respect to time, using equations defined above we can substitute to write the equation for power as:

$$P = VI$$

A Kilowatt hour is a unit of energy, using the above formula we can calculate a kWh is 3.6MJ, that's 3,600,000J. This is the unit by which you are billed and will typically cost between 5p and 10p.

Resistance and Conductance

A resistor converts electrical energy to other forms (most often heat) when current flows through it.



The voltmeter measures the “potential difference” across the component.
 R , Resistance is measured in Ohms, Ω .

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

G , Conductance is measured in Siemens, S .

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

Conductance, the reciprocal of Resistance is a more logical way of expressing the concept of resistance, a measure of the number of free electrons or “charge carriers” available in the sample.

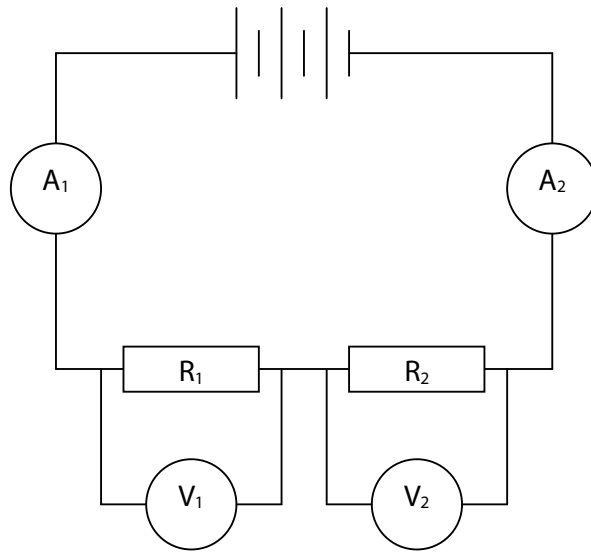
Ohms law states that for a passive conductor potential difference is proportional to current, provided that physical conditions (primarily temperature) remain constant. From this the above equations are derived.

Resistors in series

See diagram on next page.

It can be derived, using that current does not vary in the circuit, that the sum of the two voltages is equal to the total voltage and from Ohms law, that the following is true of resistors in a series circuit (*Where R_T is the total resistance*):

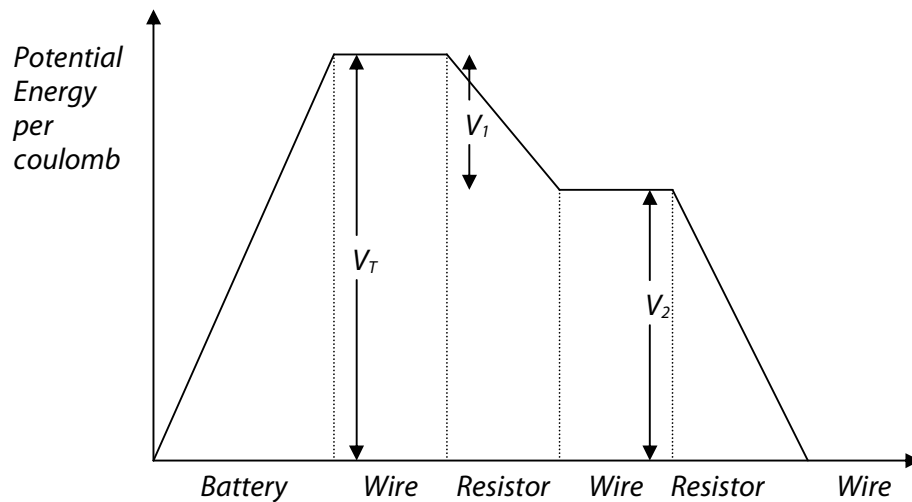
$$R_T = R_1 + R_2$$



Current is constant throughout the circuit, so it is true to say that, in series:

$$A_1 = A_2$$

To evaluate the change in potential difference around the circuit the following analogy may be of use. Wires have negligible resistance and so are modelled as being superconductors – having no resistance.



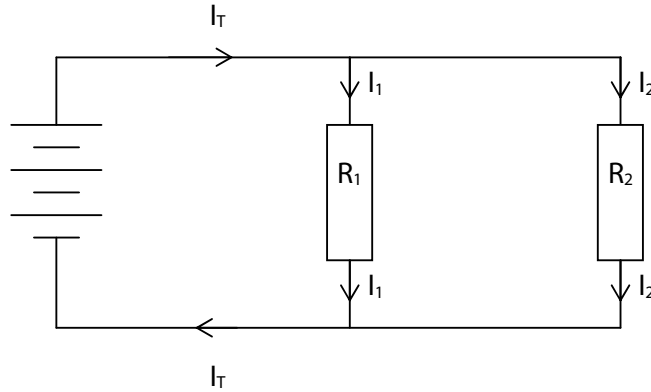
This demonstrates the concept that:

$$V_T = V_1 + V_2$$

Which is a crucial part of the proof that $R_T = R_1 + R_2$.

Resistance in parallel

Voltage is the same across all branches of a parallel circuit. The current on the different branches adds up to the total current, and the inverse resistance equals the sum of the inverse resistances.



Sum of current in parallel:

$$I_T = I_1 + I_2$$

Sum of total resistance, in parallel:

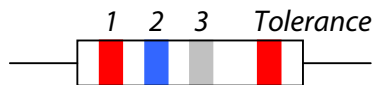
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

So the sum of conductance in parallel circuits can be written:

$$G_T = G_1 + G_2$$

In parallel the sum of conductances give the total conductance. In series the sum of the total resistances gives the total resistance.

Resistor colour codes



- 0.1 = Gold
- 0 = Black
- 1 = Brown
- 2 = Red
- 3 = Orange
- 4 = Yellow
- 5 = Green
- 6 = Blue
- 7 = Violet
- 8 = Grey
- 9 = White

Tolerance:

- (nothing) = $\pm 20\%$
- Silver = $\pm 10\%$
- Gold = $\pm 5\%$
- Red = $\pm 2\%$

1 is the first digit, 2 is the second digit. 3 is the number of zero's following these two digits. Tolerance states the precision of this figure.