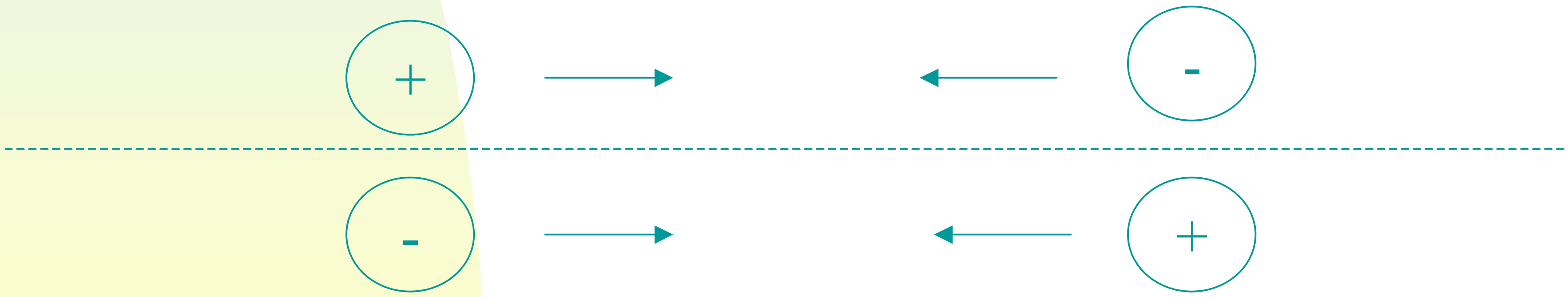
Physics in the classroom

Lecture 6

Electricity: a shocking subject

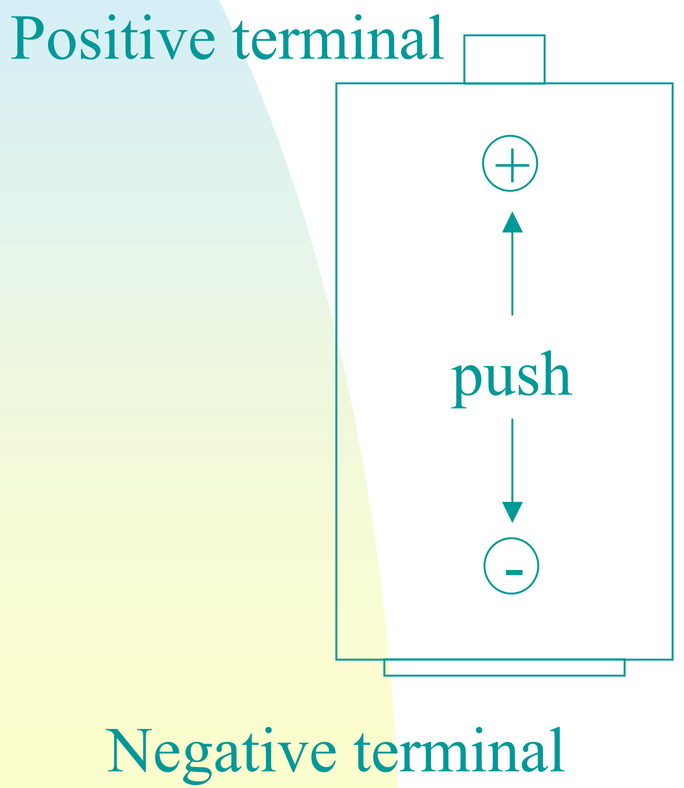
Like charges repel

Unlike charges attract



Battery

Batteries convert chemical energy into electrical energy by separating charges.



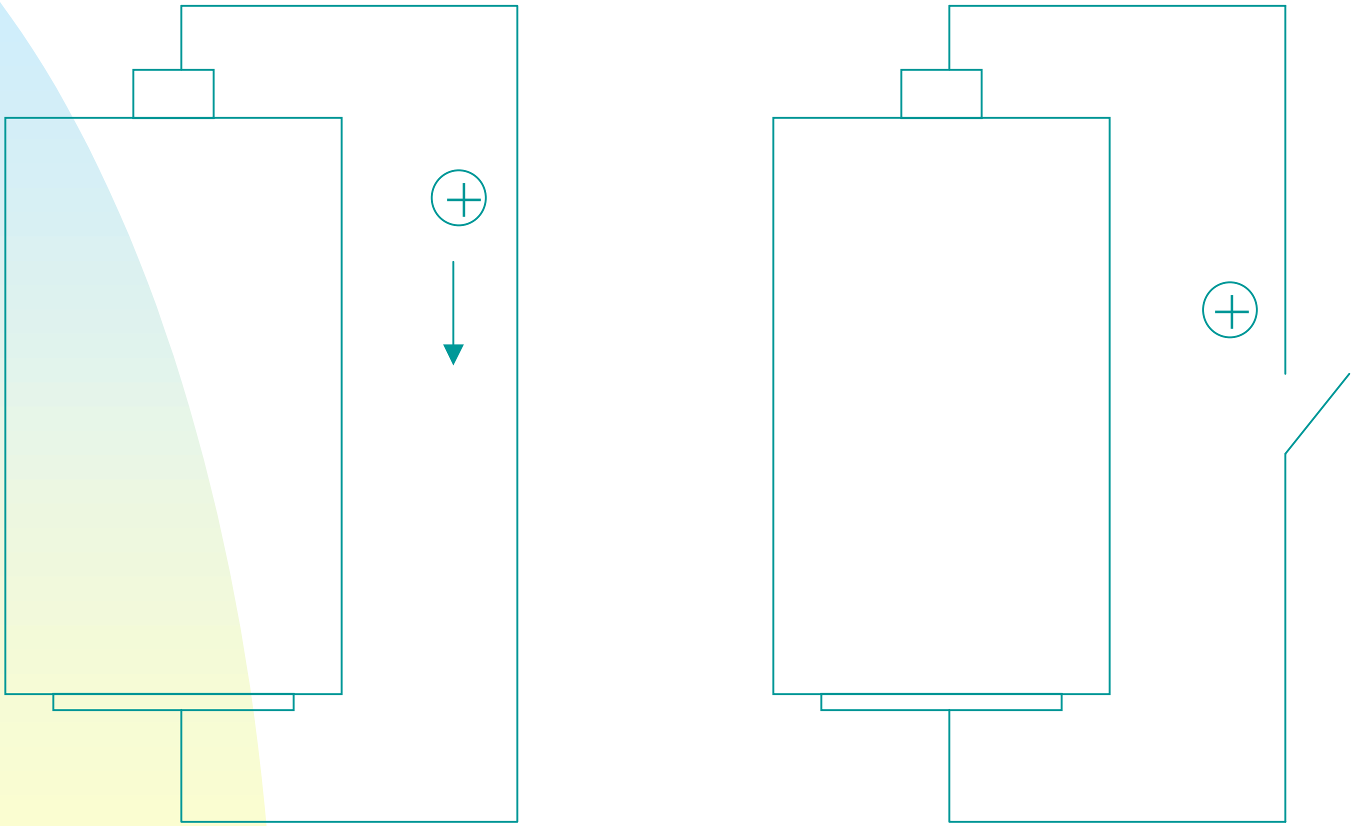
Volts

A battery has electric potential, which is measured in volts

A voltmeter can be used to measure the electric potential, sometimes referred to as the voltage.

A voltage measurement is a relative measurement, much like distance. When measuring distance we place a ruler at one end and measure to the other end. In much the same way, a voltage measurement is a measurement form one point to another.

Closed or open circuit

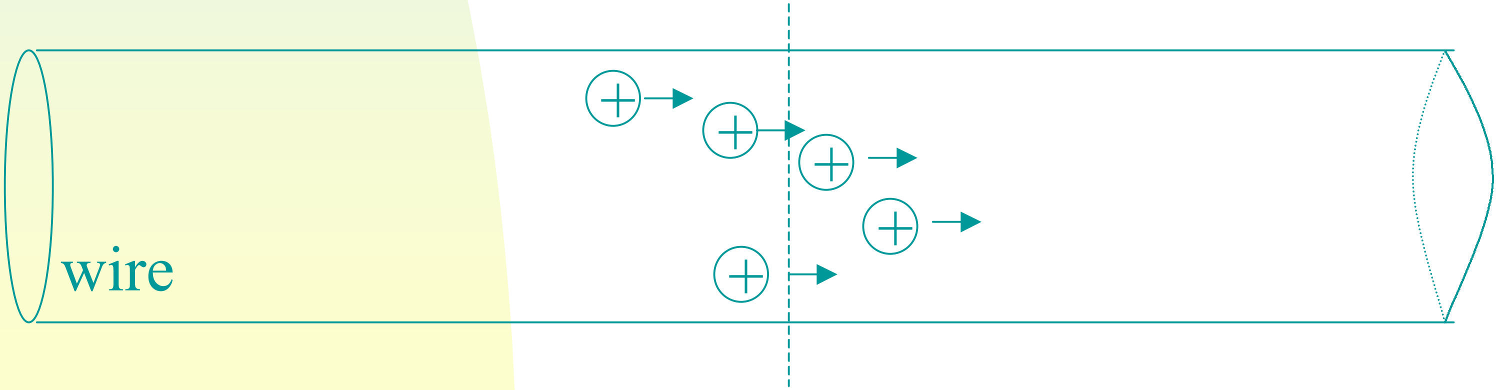


Closed: charges can flow Open: charges can not flow

Electric current

Electrical current (I) is a measure of the rate at which charges flow, in direct analogy with water current. Water current depends on the amount of water and how fast it is flowing.

Electrical current (I) is defined as the amount of charge passing an arbitrary point per unit time.

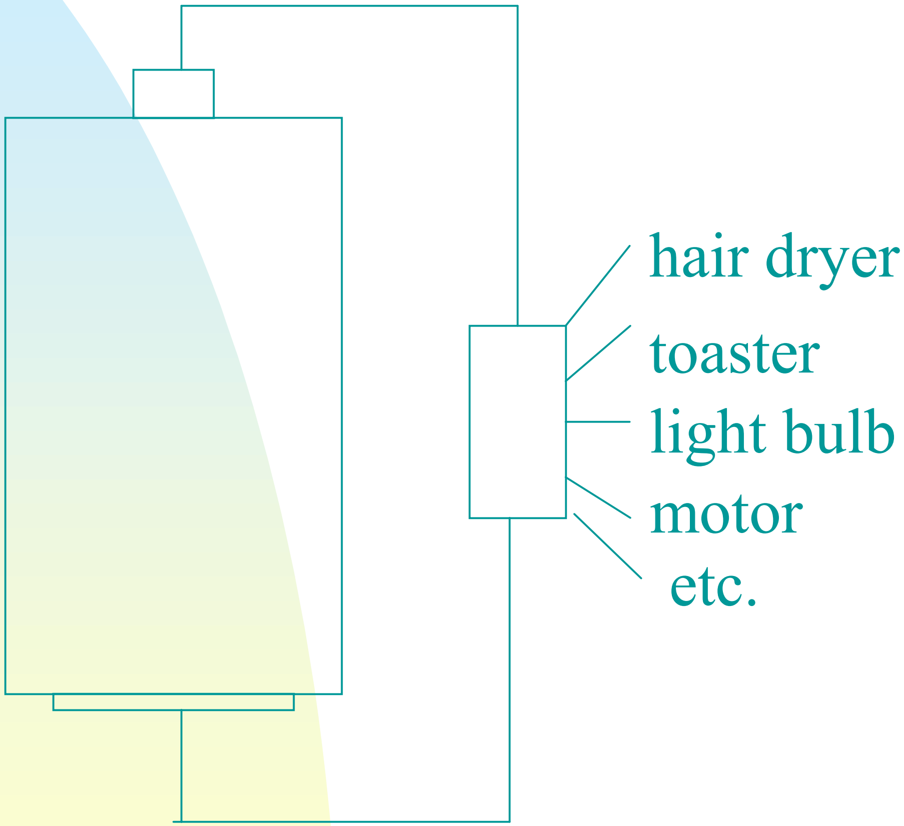


Ampere

The unit for electrical current is the Ampere (A).

An instrument called an ammeter can be used to measure electrical current. It is used by breaking the electrical circuit and inserting the ammeter, so as to measure the current flowing through it.

Using electrical current



All of these resist the flow of electrical current.

Resistance

Anything that resists the flow of electrical current has a resistance. In fact there are electrical components that are specifically designed to do that. They are called resistors.

The unit of electrical resistance is ohms and is abbreviated with the Greek symbol Ω.

Resistance is usually denoted by the letter R.

Ohm's law

The resistance (R) current (I) and voltage are all mathematically related through an important relation known as Ohm's law.

Let's see if we can reason out this law.

What happen to the current as the resistance increases?

The current decreases as the resistance increases.

In shorthand form

$$I \propto \frac{1}{R}$$

Ohm's Law continued

How does the current (I) change as the voltage (V) is increased?

The current (I) increases as the voltage is increased

In short hand form

$$I \; \alpha \; V$$

Putting it all together

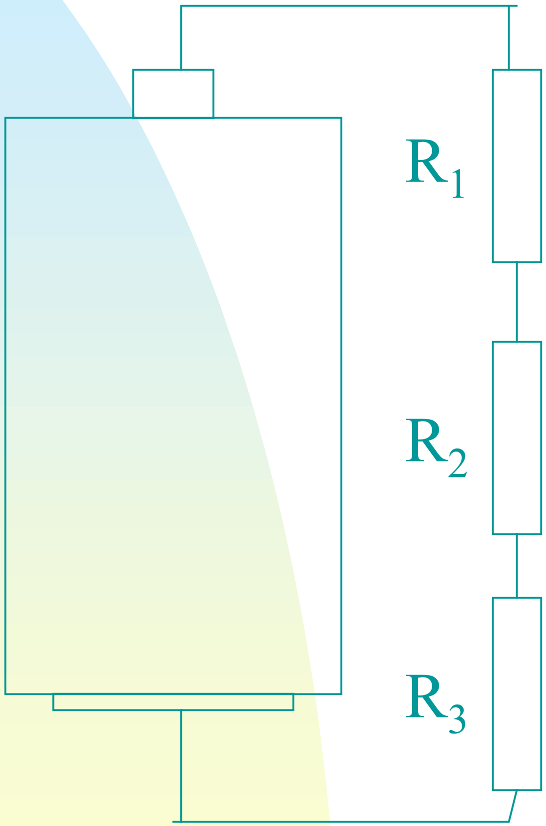
$$I = \frac{V}{R}$$

Rearranging algebraically

$V = IR$

This is perhaps the most important equation in all of electronics. More importantly for you, you will almost certainly need to understand it and understand how to use it for the final exam.

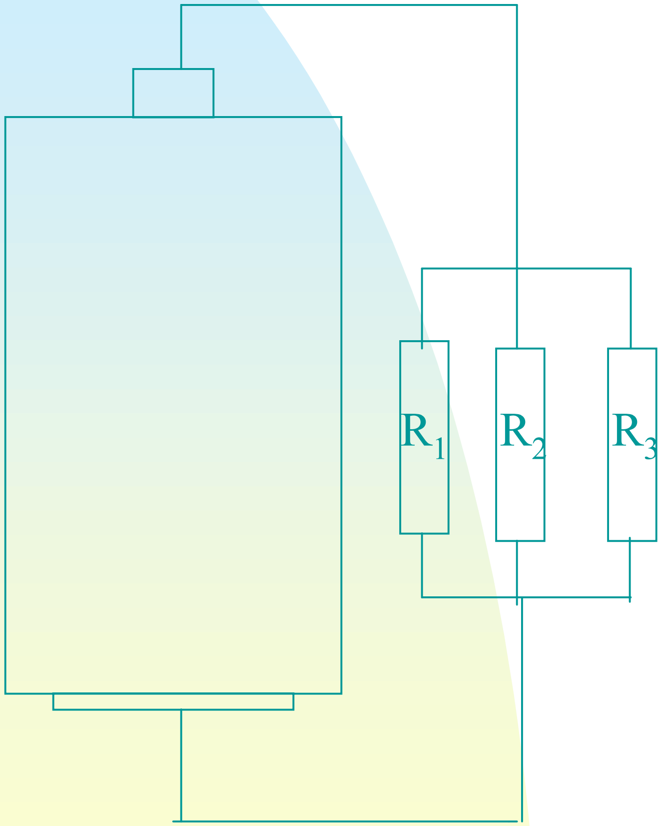
Resistors in series



Resistors in series add. This should be fairly intuitive.

$$R_{total} = R_1 + R_2 + R_3$$

Resistors in parallel



Resistors in parallel add reciprocally. This may not be as intuitive as resistors in series.

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Resistors in parallel (example)

$$R_{total} = \cfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

If $R_1 = 2\Omega$; $R_2 = 5\Omega$; and $R_3 = 10\Omega$

so

$$R_{total} = \cfrac{1}{\frac{1}{2} + \frac{1}{5} + \frac{1}{10}} = \cfrac{1}{0.5 + 0.2 + 0.1} = 1.25\Omega$$

Resistors in parallel (why?)

Notice that in our example the total resistance 1.25 Ω is less than any of the individual resistors (2Ω, 5Ω, or 10Ω). How can this be?

An analogy with LA area traffic may help. Think of parallel resistors as parallel lanes of traffic. Any single lane may be slow (high resistance) but the net effect of many lanes is to increase traffic flow.

Electrical power

Electrical power is typically abbreviated as P. Electrical power increases when the voltage is increased (bigger battery) and/or when electrical current is increased (lower resistance). In general, power is the time rate at which energy changes.

In shorthand

$$P = I\ V$$

Electrical power (units)

The unit of energy is the Joule, usually abbreviated (J)

The unit of electrical power is Watt, usually abbreviated as (W).

A Watt is equal to a Joule per second.

Example of electrical power from everyday life.

The electric company charges you for the amount of electrical energy you consume. The electric company meters the electrical energy in terms of kilowatt * hours, that is kilowatts times hours, which is actually a unit of energy.

$$1 \text{ kilowatt} * 1 \text{ hour} = 1000 \frac{\text{joule}}{\text{seconds}} \times 3600 \text{ seconds}$$

$$= 3.6 \text{ megajoules}$$