Section 1 - From the Wall Socket

Electrical Energy and Power Ratings

Batteries and the **mains** are sources of **electrical energy**. Electrical appliances can then convert this into other forms of energy.

e.g.	toaster	electrical to heat energy
	food mixer	electrical to kinetic energy
	television	electrical to light and sound

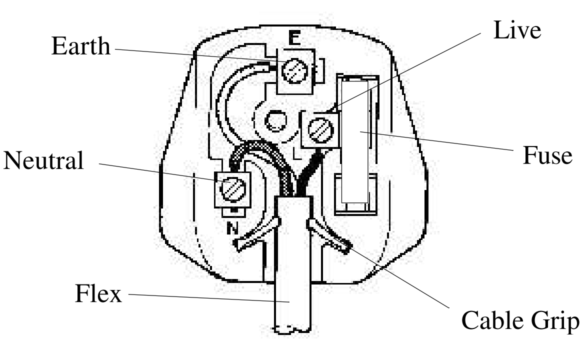
The **power rating** of an appliance is how much energy the appliance uses each second. Power rating is measured in **watts (W)** or **kilowatts (kW)** (1 kW = 1,000 W). Appliances that produce heat energy tend to have high power ratings

e.g.	kettle	2 kW
	lamp	60 W
	fridge	300 W

The Plug

The colour code for wiring a plug is:

Live	- Brown
Neutral	**-** Blue
Earth	- Yellow and Green



The Fuse and switch are always connected to the Live wire so that the high voltage is cut off from the appliance when it is switched off or the fuse has blown. This prevents electrocution.

Fuses

Fuses **protect flexes** from overheating.

Fuses are made from a thin piece of wire that will melt and break ('blow') when too large a current passes, therefore cutting off the mains supply.

Fuses are chosen according to the **power rating** of the appliance:

3 A fuse for less than 675 W
13 A fuse for greater than 675 W
Except:
If the appliance has an electric motor a 13 A fuse is always used.

Flexes

The correct flex (or cable) should be used for an appliance. The flex should be thick enough to carry the required current without overheating. The size of flex required for an appliance depends on it's **power rating**.

The Earth Wire

The Earth wire acts as a safety device.

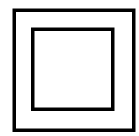
The Earth wire provides an easy path for electricity to flow to ground.

At the appliance end the Earth wire is connected to the metal casing of the appliance so that, if a fault develops to make the casing ‘live’, a large current passes and the fuse ‘blows’. This prevents anyone who touches the casing from getting an electric shock

Double insulation

Appliances that have plastic casings are said to be **double insulated** and do not require an Earth wire since there is no risk of electrocution from the casing. They therefore only use 2-core flexes (Live and Neutral).

The symbol used to identify a double insulated appliance is:



Electrical Safety

Dangerous situations with electricity include the following:

Proximity of water	Water increases the ability of the human body to conduct electricity. This therefore increases the risk and severity of electrocution.
Wrong fuses	If the fuse rating is too high the fuse will not ‘blow’ when a fault develops. This could result in the flex overheating and a fire being started.
Frayed flexes	If the insulation on a flex becomes damaged there is a risk that the Live wire could become exposed. This could result in electrocution.
Wrongly connected flexes	If flexes are wired incorrectly there is a risk of a **short circuit** (resulting in flexes overheating and a fire) or that **Earth wire** will not function correctly (resulting in electrocution).
Badly connected flexes	If a flex comes loose there is a risk of a **short circuit** or electrocution.
Short circuit	A short circuit causes a large current to pass. This could result in the flex overheating and a fire being started.
Misuse of multiway adapters	Too many appliances being connected to the same socket could cause a large current to be drawn from the mains supply. This could result in the mains wiring overheating and a fire being started.

Section 2 - Alternating and Direct Current

Current

Current is the movement of **electric charge** around a circuit.

Current can pass through a **conductor** because there are electrons (negative charge) that are free to move. Metals are good conductors of electricity.

Current cannot pass through an **insulator** since there are no charges that are free to move. Plastics, glass and air are good insulators.

Current is measured in **amperes**

Electric charge is measured in coulombs (C)

Voltage

Voltage is a measure of the energy given to the charges in the circuit .

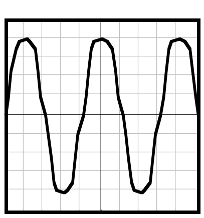
Voltage is measured in **volts**

a.c. and d.c.

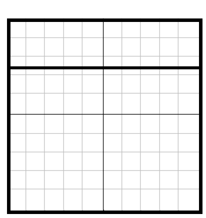
Alternating current (a.c.) is when the current changes direction every fraction of a second. The mains supplies a.c.

Direct current (d.c.) is when the current passes in one direction only. Batteries supply d.c.

The difference between a.c. and d.c. can be seen by connecting the supplies to an oscilloscope



a.c.



d.c.

Mains frequency and voltage

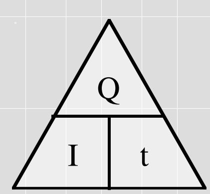
In the UK mains frequency is 50 Hz and mains voltage is 230 V.

The peak value of an a.c. supply is greater than the declared value (the r.m.s. value)

Current, Charge and Time

$$\text{current} = \frac{\text{charge}}{\text{time}}$$

current: A; charge: C; time: s

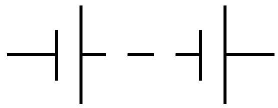


$Q = I\,t$

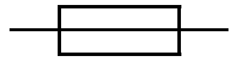
$I = \dfrac{Q}{t}$

$t = \dfrac{Q}{I}$

Components and Symbols

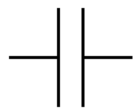


battery
converts chemical energy to electrical energy

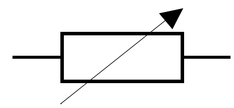


fuse
protects flexes from large currents and overheating

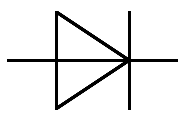
resistor
reduces current



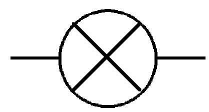
capacitor
blocks d.c. but allows a.c. to pass



variable resistor
allows the current to be controlled



diode
allows current to pass one way only



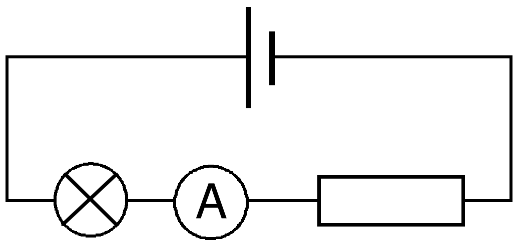
lamp
converts electrical energy to light

switch
allows current to be turned on and off

Section 3 - Resistance

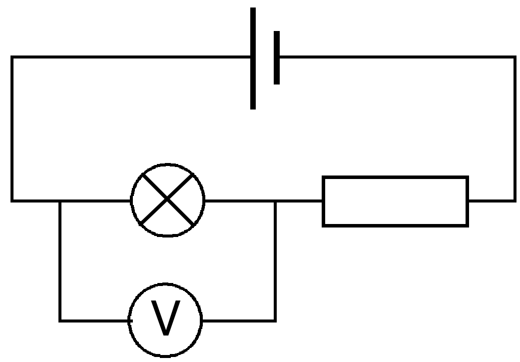
Measuring Current

In order to measure the current in a circuit an **ammeter** should be placed in series:



Measuring Voltage

In order to measure the voltage in a circuit a **voltmeter** should be placed in parallel:



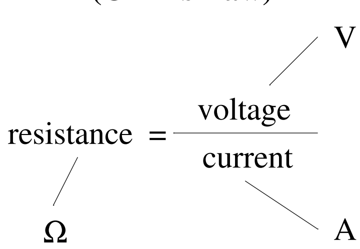
Resistance

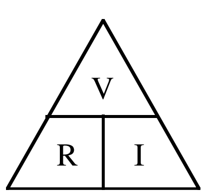
Resistance is t*he difficulty charges have in moving through a material*. Increasing the resistance in an electrical circuit decreases the current in the circuit.

Resistance is measured in **ohms (Ω)**.

For a given resistor the ratio V/I remains approximately constant even when the current changes. This is defined as the resistance of the resistor

Resistance, Current and Voltage
(Ohm's Law)





$V = IR$

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

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

Variable Resistors

Variable resistors can be used to alter the current in a circuit. For example variable resistors are used in the volume controls of radios and the petrol gauges of cars.

Resistance and Heat

Whenever there is a current in a wire some electrical energy is converted into heat due to the resistance of the wire. This effect is used in electric fires, kettles, toasters and cookers.

Power and Energy

Electrical **power** is the *rate at which electrical energy is converted into other forms*. This is equal to the current (charge per second) multiplied by the voltage (energy per charge).

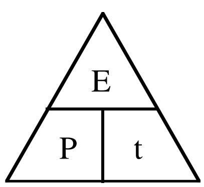
Electrical power is measured in watts (W).

Electrical energy is measured in joules ,(J).

Power, Energy and Time

$$\text{power} = \frac{\text{energy}}{\text{time}}$$

W   J   s



$E = P\,t$

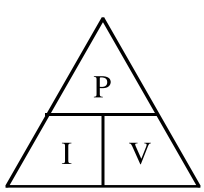
$P = \frac{E}{t}$

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

Power, Current and Voltage

$$\text{power} = \text{current} \times \text{voltage}$$

W   A   V



$P = IV$

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

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

Energy Transformations

In a lamp electrical energy is transformed into heat and light. In a filament lamp this transformation occurs in the resistance wire and in a discharge tube it occurs in the gas).

Discharge tubes are more efficient than filament lamps as more of the energy is transformed into light and less into heat)

In electric heaters (e.g. toaster, cooker and electric fire) energy transformation occurs in the resistance wire (element) of the appliance.

Equivalence of $P=IV$ and $P=I^2R$

The two formulae $P=IV$ and $P=I^2R$ can be shown to be equivalent:

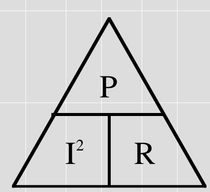
We know that $P=IV$
but also $V=IR$ (from Ohm's Law).

Therefore $P = I\,(IR)$
$P = I^2R$

Power, Current and Resistance

$$\text{power} = \text{current}^2 \times \text{resistance}$$

W   A   Ω



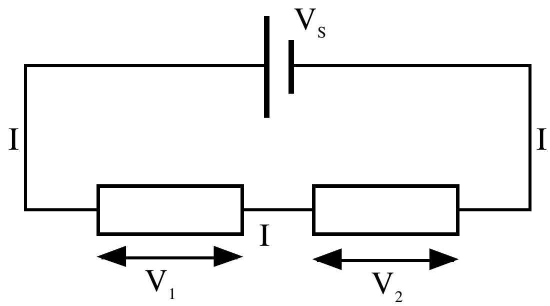
$P = I^2R$

$I^2 = \frac{P}{R}$

$R = \frac{P}{I^2}$

Section 4 - Useful Circuits

Series Circuits



There is only one path for current in a series circuit and so the current is the same at all points.

The sum of all the voltages across components in series is equal to the supply voltage :

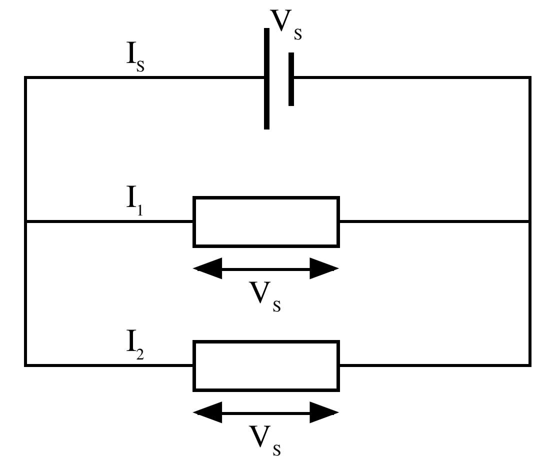
$$V_S = V_1 + V_2 + ...$$

Switches can also be placed in series in which case both switches must be closed for the circuit to operate. For example a central heating system must both be switched on and the thermostat switch activated for it to operate

In a series circuit the total resistance of the circuit, R_T, is given by the formula:

$$R_T = R_1 + R_2 + ...$$

Parallel Circuits



In a parallel circuit the sum of the currents in each branch of the circuit is equal to the current drawn from the supply:

$$I_S = I_1 + I_2 + ...$$

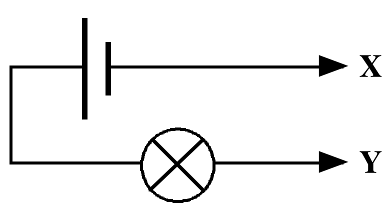
The voltages across components in parallel is the same for each component

Sockets in the home are connected in parallel. Care must be taken not to connect too many appliances to the one socket since this could result in a large current being drawn from the supply

In a parallel circuit the total resistance of the circuit, R_T, is given by the formula:

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

Continuity Tester



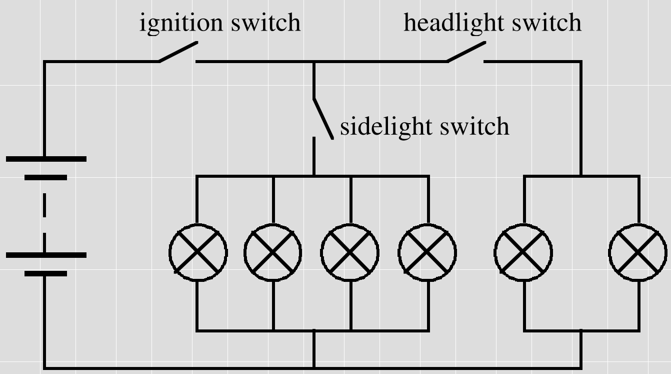
A simple **continuity tester** can be made using a battery and a bulb as shown opposite.

The circuit to be tested is placed between X and Y.

If the bulb lights there is a continuous circuit.

Car Lighting Circuits

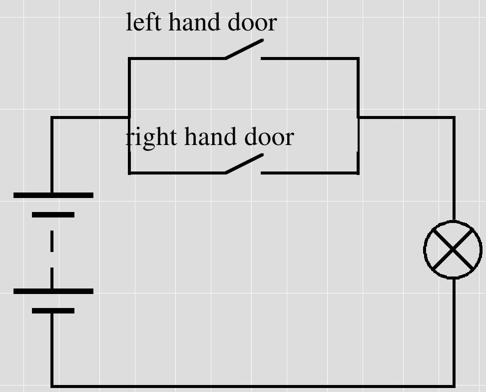
Headlights and Sidelights



All bulbs are placed in parallel so each bulb has 12V across it and so that if one bulb blows the others stay on.

The ignition switch is placed in series so that this must be switched on in order for either the sidelights or headlights to work.

Courtesy Light



The two switches are placed in parallel so that when either door is opened the courtesy light will come on.

Section 5 - Behind the Wall

Household Wiring

Household wiring connects all appliances in **parallel** so that each receives the full supply voltage and that if one appliance is switched off the others remain on.

kilowatt-hours

Electricity supply companies charge their customers per kilowatt-hour (kWh) of energy used. The kilowatt-hour is a unit of energy.

1 kWh = 1 kW for 1 hour

and

no. of kWh used = no. of kW x no. of hours

To convert from kilowatt-hours into joules change kilowatts into watts and hours into seconds:

1 kW = 1,000 W
1 hour = 60 x 60 s = 3,600 s

Then P = Et
P = 1,000 x 3,600
P = 3,600,000 J

Differences between power and Lighting Circuits

Lighting Circuit	Socket Circuit
simple parallel	ring
5 A max	30 A max
thin cable	thick cable

Fuses and Circuit Breakers

Mains fuses protect the mains wiring from overheating and causing a fire if too large a current is drawn. These are found in the fuse box.

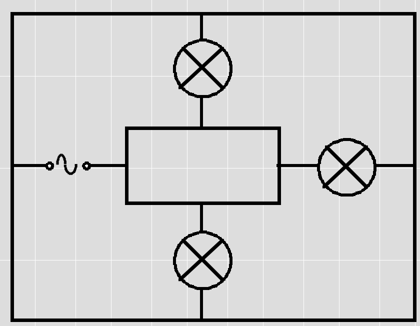
Nowadays many fuses have been replaced by circuit breakers. These are simply automatic switches which trigger when too large a current is drawn.

Circuit breakers have the advantage over fuses in that they can simply be reset and used again.

Ring Circuits

Sockets in the home are connected in a special type of parallel circuit called a **ring circuit**.

e.g.



Ring circuits have the following advantages:

i) There is less current in each wire since there is more than one path to each socket.

ii) Thinner cable can be used since there is less current.

iii) There is less risk of overheating with a smaller current.

Section 6 - Movement from Electricity

Magnetic Fields and Electric Currents

When current passes through a wire a magnetic field is produced around the wire.

When a current carrying wire is placed in a magnetic field there is force on the wire

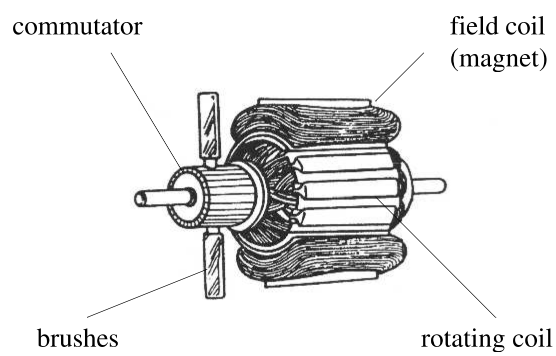
The magnetic effects of current are used in devices such as electric bells, electromagnets, relays and motors.

Current, Magnetic field and Force

Electric current, magnetic field and force (or movement) are inter-related quantities. If two of these are present the third will be produced.

When a current carrying wire is placed in a magnetic field the force on it will depend on both the direction of the current and the direction of the magnetic field. Reversing either of these will reverse the direction of the force on the wire.

Electric Motors



In an electric motor the **field coils** (or magnets) produce an magnetic field. The **rotating coil** carries a current in the magnetic filed and therefore there is a force on the rotating coil.

In order to keep the motor turning in the same direction the **commutator** reverses the direction of current in the rotating coils every half turn.

The **brushes** make electric contact with the commutator while allowing it to rotate.

Commercial Motors

Commercial motors have:

- **carbon brushes** to provide good electrical contact to the commutator without creating too much wear on the commutator.
- **field coils** instead of permanent magnets in order to provide a stronger magnetic field.
- **multi-section commutators** to keep the turning force large and the rotation smoother.