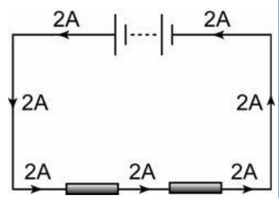
Physics Knowledge Organiser
Topic : Electricity

Electric charge and current

Every atom contains particles with an electric charge: protons and electrons. By getting electric charges to **flow**, we can get them to do work (i.e. transfer energy) in all sorts of useful ways. For that is what happens in any electric circuit you can think of: *flowing charges transfer energy*.

If we want to get electric charges to flow, we must make a **closed**, or complete circuit – a loop of conducting materials, like metal wires. Then, we must provide a source of **potential difference**. The source of potential difference could be a cell, battery or the mains. What these sources do is to create a *difference* in electrical *potential* energy – hence the name. This provides the force to make the **electric charges** in the conductors **flow**. When electric charges, like electrons, are flowing, we call it an **electric current**.

The size of an electric current is simply the **rate** of flow of electric charge.
So current (I) = $\frac{Q}{t}$ or $Q = It$



In a circuit, in any closed loop of the circuit, the size of the current is the same throughout the loop. As shown on the diagram, the current is the same in all parts of the loop, including through the battery and through the resistors.

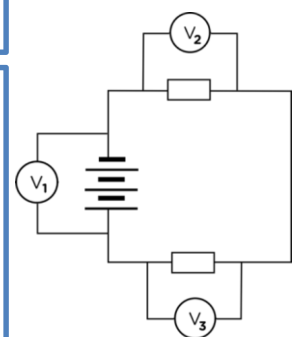
Current, resistance and potential difference

Cells and batteries etc. are **sources** of potential difference. This means they boost the potential energy of charges in a circuit. Other components, like resistors or bulbs, do **work** – so they take the potential energy of the charges and **transfer** it into some other form, like light or heat. In a circuit, all the energy provided by the cell/battery is transferred by the components in the circuit all together. So, in components like bulbs, the charges do work – i.e. they transfer energy. By definition, this means they have a potential difference **across** them. We say 'across' since it is a difference, from one side of the component to the other.

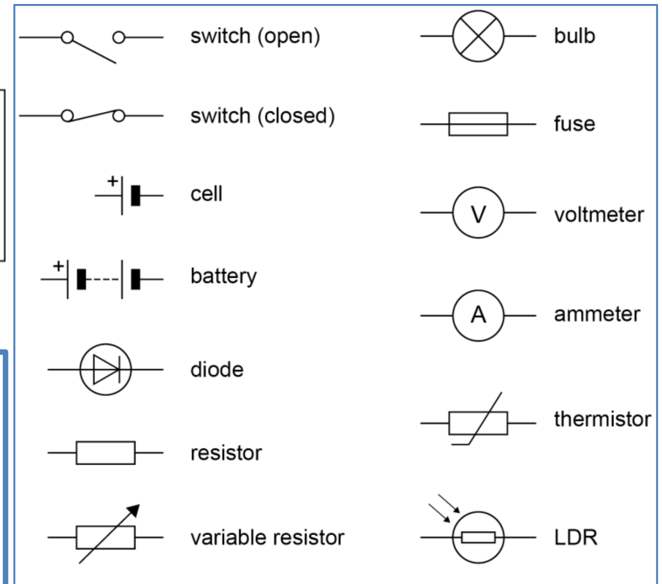
The current through a component depends on this potential difference across the component, but also its **resistance**. Without any resistance, a component would <u>do no work</u> (try putting a 0 in the equation!), so things like bulbs HAVE TO have resistance. The resistance of a component, along with the potential difference across it, determines the current through it, as shown in the second equation. It shows us that: if we keep the potential difference the same, but increase the resistance, the current must *decrease*. If we keep the potential difference the same, but decrease the resistance, the current must *increase*.

Key Terms	Definitions
Electric charge	Just a positive or negative charge! In most electrical circuits, the electric charges that are flowing are **electrons** – which are of course negatively charged. Symbol: *Q*
Current	The rate of flow of electric charge (i.e. speed). Calculated by dividing the size of the charge by the time. Symbol: *I*
Potential difference	Also known as voltage, or p.d.. The potential difference is a measure of how much work is done per coulomb of charge.
Resistance	Resistance determines the size of the current for a particular potential difference.

Equation	Meanings of terms in equation
* $Q = I\,t$	*Q = charge flow (coulombs, C)* *I = current (amperes, A)* *t = time (seconds, s)*
* $V = I\,R$	*V = potential difference (volts, V)* *I = current (amperes, A)* *R = resistance (ohms, Ω)*



Look how the voltmeters are added **across** the components to measure the potential difference across them.



Yes, you need to learn these symbols.

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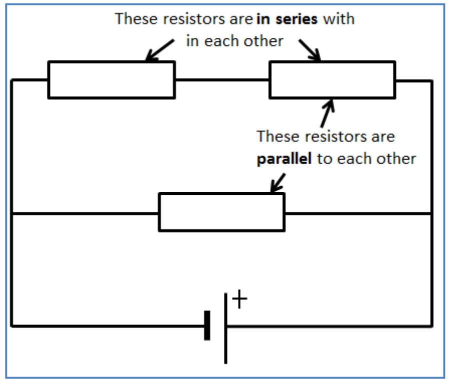
Series and parallel circuits

We can connect components in a circuit in series or in parallel. In some circuits, there are components in series AND components in parallel – see the example in the diagram.

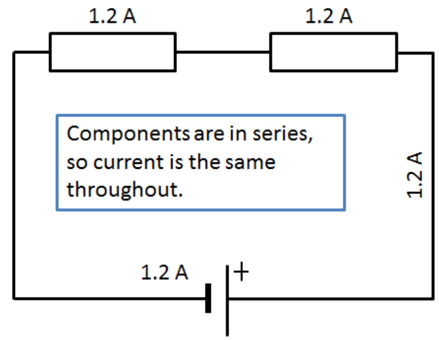
The quantities of resistance, current and potential difference behave differently in components connected in series compared to components connected in parallel. Study the table and diagrams carefully.

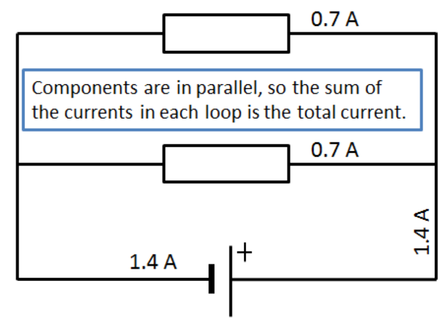


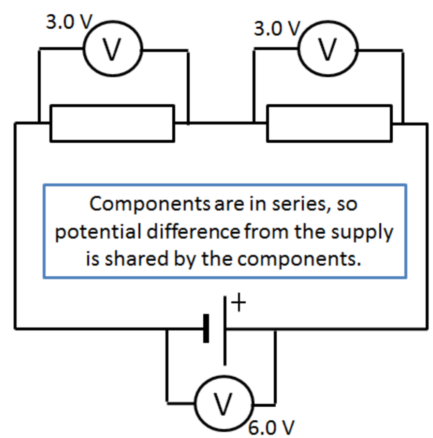
Quantity	Components connected in series…	Components connected in parallel…
Current	The current through each component is identical	Shared between the loops. The total current through the whole circuit is the **sum** of the currents through each loop of the circuit.
Potential difference	The potential difference provided by the power supply is shared between the components in series (not necessarily equally shared out – it depends on the resistance of each component).	Each loop receives the full potential difference provided by the power supply. If we are dealing with just two components in parallel, the potential difference across each is exactly the same, and exactly the same as the potential difference provided by the power supply.
Resistance	The total resistance of two components is the **sum** of the resistance of each component (see equation). So, adding more resistors in series *increases* the total resistance.	The total resistance of two components in parallel is always **less** than the smallest resistance of the components. As a result, adding **more** resistors in parallel actually *decreases* the overall resistance.

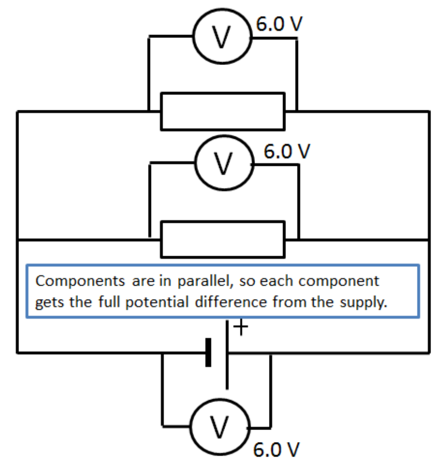
Key Terms	Definitions
Series	Components connected one after another in a closed loop.
Parallel	Components connected in different loops of a circuit.
Resistor	An electrical component that regulates current in a circuit. Bear in mind, all electrical components have **resistance**, so are resistors in some sense, as well as being e.g. bulbs.

Equation	Meanings of terms in equation
for series circuits: $R_{total} = R_1 + R_2$ *	R_{total} = *total resistance (ohms, Ω)* R_1 = *resistance of first component (Ω)* R_2 = *resistance of next component (Ω) – and so on*









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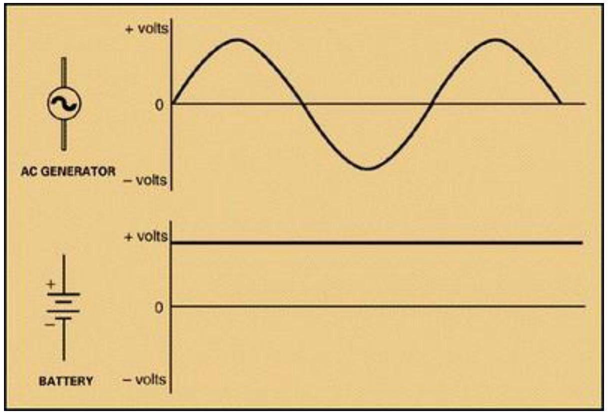
Direct and alternating potential difference

The flow of charge (current) in a circuit can travel in one direction around the circuit only. This is due to a **direct** supply of potential difference, also known as dc. Cells and batteries provide a direct potential difference. However, it is possible for the direction of the current to change back and forth in a circuit. This happens when there the supply provides an **alternating** potential difference – also known as ac. This means the p.d. is constantly switching from positive to negative, which you can see if you measure the p.d. and produce an image of is on an **oscilloscope**, as the diagram shows. The rate at which the p.d. switches from positive to negative is called the <u>frequency</u> of the supply. The bottom image, since the supply is a battery, shows a direct potential difference.



Three-core cables

We connect most electrical appliances to the mains with a three-core cable. The three pins on a plug are just the three ends, or terminals, of the three wires in the cable. Each wire in insulated in a different colour.

Mains electricity

Mains electricity (the supply into your house/school etc. that comes through the plugs) is an ac supply. In the UK, we have a supply with a p.d. of about 230V, and the frequency is 50 Hz.

Wire in three-core cable	Colour code of the insulation	Function
Live wire	Brown	Carries the alternating p.d. from the supply to the appliance
Neutral wire	Blue	Completes the circuit. The neutral wire is at 0 V (earth potential).
Earth wire	Yellow and green stripes	Earth wires are at 0 V. They are safety wires, and only carry a current if there is a fault and the appliance has become live (electrified).

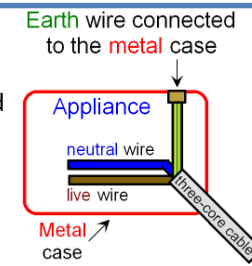
Key Terms	Definitions
Direct p.d.	A supply where the potential difference is fixed at a certain value, so the current flows in one direction only
Alternating p.d.	A supply where the p.d. switches between positive a negative, reversing the direction of the current frequently.
Frequency	The number of times the p.d. reverses direction every second. Measured in Hertz (Hz).

The national grid

The national grid connects power stations to consumers of the power – like you. It consists of a network of cables (i.e. power lines) and **transformers**. There are two types of transformers; together they improve the efficiency of the energy transfer from power station to homes and schools etc.:

1. Step-up transformers ***increase*** the p.d. from the power station to the transmission cables. This reduces the current so less energy is lost as heat.
2. Step-down transformers ***decrease*** the p.d. from the cables to a much lower value (230V, generally) for domestic use. This increases the current to suit electrical appliances used at home.

DANGER (and safety)



The earth wire carries current to the ground (literally, earth). This makes circuits safer because if there is a fault, it conducts the current to the ground rather than making the appliance 'live'. Appliances become live if the live wire touches the case. This is particularly a problem with metal-cased appliances, like cookers or toasters.

The live wire is the most dangerous one, since it is at 230 V. it should never touch the earth wire (unless the insulation is between them, of course!), because this would make a complete circuit from your mains supply to the ground (earth). A shock or fire would be highly likely.

Even if a circuit is switched off (i.e. the switch is **open**), the live wire can still be dangerous. If you touch it, you may complete a circuit between the live wire and the earth (because you'll be standing on the floor), so you get a shock.

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Power

You should recall that power is **the rate of energy transfer**, or the rate at which work is done. In electrical components, including any electrical appliance, the power relates to the potential difference across the component and the current through it. If either p.d. or current increases, the power increases. In other words, the rate of energy transfer increases. This should be clear from the first equation.

The second equation also finds the power. The equation comes from substituting in $V = IR$. The second equation is useful if you don't know the p.d. across a component.

Energy transfers in electrical appliances

The whole point of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful – such as light and sound in your TV. The other way of saying this is that **work is done** when **charge flows** in a circuit.

Some examples of energy transfers in electrical appliances:
- In your mobile phone, electrical potential energy from the dc supply (the battery) is transferred to light, sound and thermal energy. This means the energy from the battery is **dissipated** to the surroundings.
- A washing machine transfers electrical potential energy from the ac mains supply to kinetic energy in the electric motor (that's why it spins), along with heat. Eventually, all the energy of the input is dissipated to the surroundings.
- An electric heater transfers the electrical potential energy of the supply to thermal energy. The energy stored in the supply ends up stored in the air, the walls, the floor and so on around the heater: stored in the heat of the materials.

The amount of energy transferred by an appliance depends on the **power** of the appliance and the **time** it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for (see third equation).

Furthermore, since p.d. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the p.d. (see fourth equation).

Key Terms	Definitions
Power	The rate of energy transfer. In electrical components, the power is found by multiplying p.d. by current.
Work	Transfer of energy.
Appliance	Any device that transfers electrical energy to other forms. The supply of electrical energy can be a cell, battery, or the mains ac supply.

Equation	Meanings of terms in equation
* $P = V\ I$	*P = power (watts, W)* *V = potential difference (volts, V)* *I = current (amps, A)*
* $P = I^2\ R$	*P = power (watts, W)* *I = current (amps, A)* *R = resistance (ohms, Ω)*
* $E = P\ t$	*E = energy transferred (joules, J)* *P = power (watts, W)* *t = time (seconds, s)*
* $E = Q\ V$	*E = energy transferred (joules, J)* *Q = charge flow (coulombs, C)* *V = potential difference (volts, V)*

High power, low power

The power of an appliance determines how much energy is transfers in a given length of time. If an appliance has a high power (e.g. a washing machine), it transfers lots of energy in a given time. If it has a low power (e.g. a lamp), it doesn't transfer much energy in a given time, in comparison.

The other way of looking at it is how long the appliance takes to transfer a given amount of energy, e.g. 1000 J. A washing machine will transfer the energy in a very short length of time, whereas a lamp will take much longer to transfer this energy.