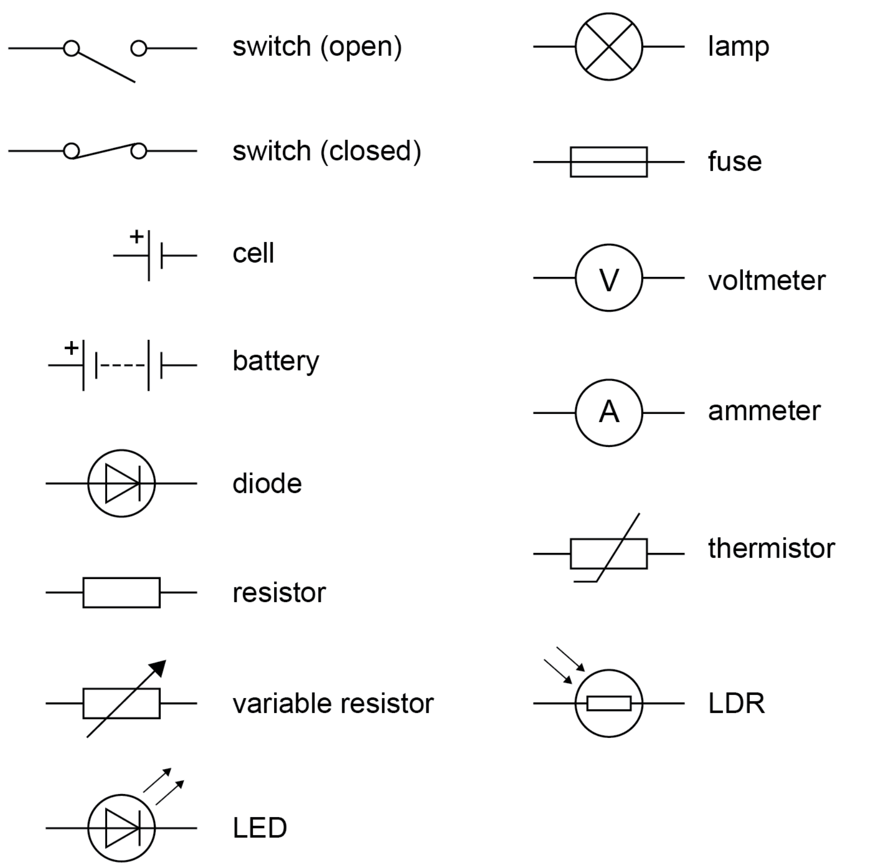
Electricity Notes - GCSE Physics

4.2.1 Current, potential difference and resistance

4.2.1.1 Standard circuit diagram symbols

Content	Additional Notes from Dr C
Circuit diagrams use standard symbols.  Students should be able to draw and interpret circuit diagrams.	You need to be able to use all these symbols correctly. They need to be exactly the same as the diagram, not your interpretation of it! For instance, note that the line does not go through the circles for voltmeters and ammeters.

4.2.1.2 Electrical charge and current

Content	Additional Notes from Dr C
For electrical charge to flow through a closed circuit the circuit must include a source of potential difference.	This means that if you want a current to flow you must put a battery in the circuit!

Content	Additional Notes from Dr C
Electric current is a flow of electrical charge. The size of the electric current is the rate of flow of electrical charge. Charge flow, current and time are linked by the equation: $charge\ flow = current \times time$ $[\ Q = I\ t\ ]$ charge flow, *Q*, in coulombs, C current, *I*, in amperes, A (amp is acceptable for ampere) time, *t*, in seconds, s A current has the same value at any point in a single closed loop.	Current is how quickly the electrons are moving round the circuit. Each electron carries a small charge, so the equation tells us that if you have a lot of charge in a short time then there is a big current. Note time is in seconds. This is a common trick in exam questions when time is given in minutes or hours and must be converted.

4.2.1.3 Current, resistance and potential difference

Content	Additional Notes from Dr C
The current (*I*) through a component depends on both the resistance (*R*) of the component and the potential difference (*V*) across the component. The greater the resistance of the component the smaller the current for a given potential difference (pd) across the component. Questions will be set using the term potential difference. Students will gain credit for the correct use of either potential difference or voltage.	Resistance is a measure of how easy it is for the electrons to get through. So if resistance is high, the electrons find it hard to get through, so move slowly which means the current is low.
Current, potential difference or resistance can be calculated using the equation: $potential\ difference = current \times resistance$ $[\ V = I\ R\ ]$ potential difference, *V*, in volts, V current, *I*, in amperes, A (amp is acceptable for ampere) resistance, *R*, in ohms, Ω	This equation gets used a lot. You can use it on the whole circuit or just on single components. Often you have to do both.

Required practical activity 3:

Use circuit diagrams to set up and check appropriate circuits to investigate the factors affecting the resistance of electrical circuits. This should include:

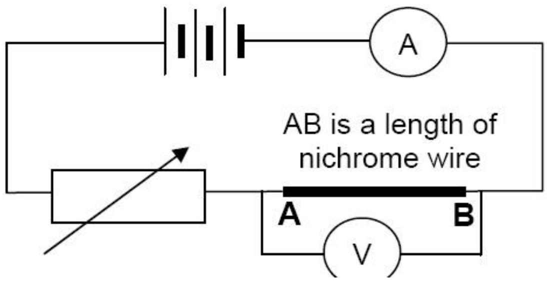
- the length of a wire at constant temperature
- combinations of resistors in series and parallel.

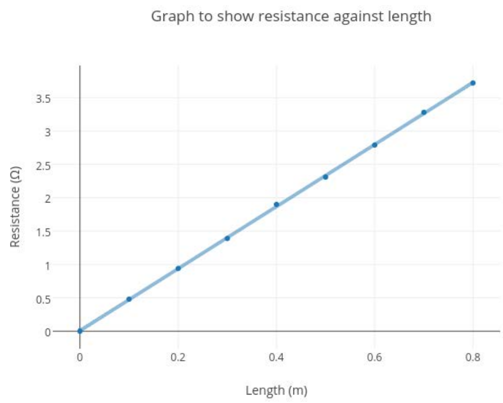
AT skills covered by this practical activity: AT 1, 6 and 7.

This practical activity also provides opportunities to develop WS and MS. Details of all skills are given in Key opportunities for skills development (page 91).

Required practical - Resistance

This is the circuit that you need. You will be expected to be able to draw this. Note that the ammeter is in series and the voltmeter in parallel across the thing you want to know the voltage across i.e. the wire in this case.



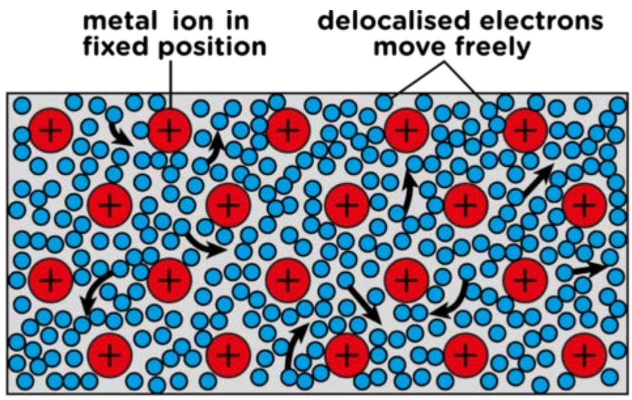


The major sources of error in this experiment are

1. the length of the wire. Because the crocodile clips have a certain width, it is difficult to get this very accurate. This can be solved by using something thinner e.g. a probe or another piece of wire, to connect the wire into the circuit.
2. When you pass a current through a wire it gets hot. this increases its resistance. This is more likely to be a problem for short lengths when the resistance is small and thus the current is high. This means your graph may not pass through the origin even though it is suppose to.
   The solution to this is to keep the current low, turn circuit off between readings and use a long piece of wire so you don't have very short lengths.

Important Point about resistance in metals.

Current is carried through a metal by the delocalised electrons. Metals have a lot of these which is why they are good at conducting electricity. The metal ions are left in their fixed positions.
When a current is passed through a metal the metal gets hotter. This means that the ions vibrate more. Therefore it is harder for the electrons to get past the ions and so the resistance increases.
The hotter the metal gets, the higher its resistance.
Note: This is only true for metals. Some circuit components are made of semiconductors for which different rules apply.

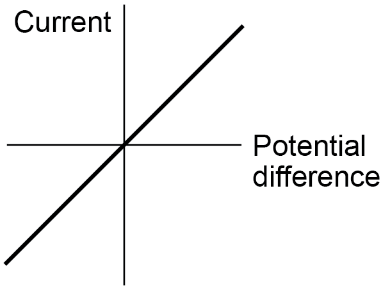


4.2.1.4 Resistors

Content

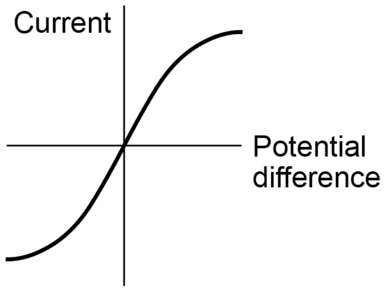
Students should be able to explain that, for some resistors, the value of *R* remains constant but that in others it can change as the current changes.

The current through an ohmic conductor (at a constant temperature) is directly proportional to the potential difference across the resistor. This means that the resistance remains constant as the current changes.

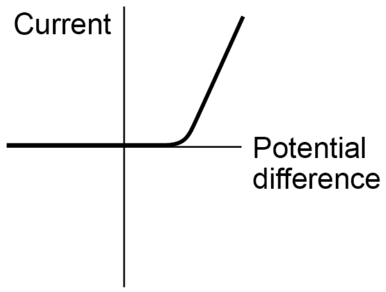


The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component.

The resistance of a filament lamp increases as the temperature of the filament increases.



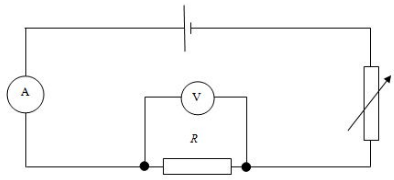
The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.



Additional Notes from Dr C

You need to be able to draw the circuit diagrams for each of these experiments and draw and explain the shape of the graphs.

The circuit required is



Just replace the resistor with light bulb or diode as required.
The variable resistor is required so that you can get different values of current and voltage so that you can draw a graph.

The gradient of the graph is 1/resistance so if the gradient is high, the resistance is low. If the gradient is small, the resistance is high.

The lightbulb graph, the gradient starts high so the resistance is low.
The gradient then gets smaller so the resistance is higher. This is because the filament gets hot as previously discussed.

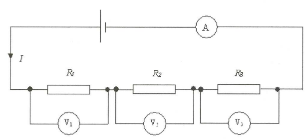
For the diode, the gradient starts at zero so the resistance is infinite (because 1/0 is infinity).
The gradient then becomes very large therefore resistance is small.

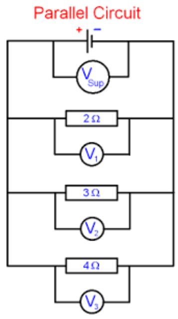
Content	Additional Notes from Dr C
The resistance of a thermistor decreases as the temperature increases. The applications of thermistors in circuits eg a thermostat is required. The resistance of an LDR decreases as light intensity increases.	Thermistors and LDR's are made of semiconductors. Note they both go the same way - the more light/ heat the lower the resistance
The application of LDRs in circuits eg switching lights on when it gets dark is required. Students should be able to:	This is how street lamps work.
• explain the design and use of a circuit to measure the resistance of a component by measuring the current through, and potential difference across, the component • draw an appropriate circuit diagram using correct circuit symbols.	This is exactly the same circuit as the resistance of the wire, but with the wire replaced by LDR or thermistor
Students should be able to use graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties.	

Required practical activity 4: use circuit diagrams to construct appropriate circuits to investigate the I–V characteristics of a variety of circuit elements, including a filament lamp, a diode and a resistor at constant temperature.

3).

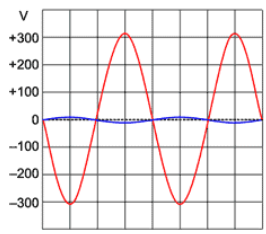
4.2.2 Series and parallel circuits

Content	Additional Notes from Dr C
There are two ways of joining electrical components, in series and in parallel. Some circuits include both series and parallel parts. For components connected in series: • there is the same current through each component • the total potential difference of the power supply is shared between the components • the total resistance of two components is the sum of the resistance of each component.	 The voltage across each of the resistances will add up to the voltage of the battery. The total resistance is the sum of the individual resistances.

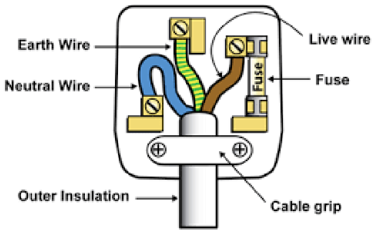
Content	Additional Notes from Dr C
$R_{total} = R_1 + R_2$ resistance, R, in ohms, Ω For components connected in parallel: • the potential difference across each component is the same • the total current through the whole circuit is the sum of the currents through the separate components • the total resistance of two resistors is less than the resistance of the smallest individual resistor. Students should be able to:	 The voltage across each of these resistors is the same. The current in each branch will add up to the total current through the battery.
• use circuit diagrams to construct and check series and parallel circuits that include a variety of common circuit components • describe the difference between series and parallel circuits • explain qualitatively why adding resistors in series increases the total resistance whilst adding resistors in parallel decreases the total resistance	Every time you add another resistor in parallel the total resistance of the circuit decreases, even if it is a big resistor. This is because there are more routes for the current to go down so electrons can go faster
• explain the design and use of dc series circuits for measurement and testing purposes	
• calculate the currents, potential differences and resistances in dc series circuits • solve problems for circuits which include resistors in series using the concept of equivalent resistance. Students are **not** required to calculate the total resistance of two resistors joined in parallel.	You need to practice these.. Plenty of examples to be found in textbook or on website.

4.2.3 Domestic uses and safety

4.2.3.1 Direct and alternating potential difference

Content	Additional Notes from Dr C
Mains electricity is an ac supply. In the United Kingdom the domestic electricity supply has a frequency of 50 Hz and is about 230 V. Students should be able to explain the difference between direct and alternating potential difference. 	You need to remember these two numbers. Alternating p.d. constantly changes direction. Direct p.d. always goes in same direction.

4.2.3.2 Mains electricity

Content	Additional Notes from Dr C
Most electrical appliances are connected to the mains using three-core cable. The insulation covering each wire is colour coded for easy identification: live wire – brown neutral wire – blue earth wire – green and yellow stripes. The live wire carries the alternating potential difference from the supply. The neutral wire completes the circuit. The earth wire is a safety wire to stop the appliance becoming live. The potential difference between the live wire and earth (0 V) is about 230 V. The neutral wire is at, or close to, earth potential (0 V). The earth wire is at 0 V, it only carries a current if there is a fault. Students should be able to explain: • that a live wire may be dangerous even when a switch in the mains circuit is open • the dangers of providing any connection between the live wire and earth.	This is pretty straightforward. You just need to learn this. 

4.2.4 Energy transfers

4.2.4.1 Power

Content	Additional Notes from Dr C
Students should be able to explain how the power transfer in any circuit device is related to the potential difference across it and the current through it, and to the energy changes over time: $power = potential\ difference \times current$ $[P = V I]$ $power$ = (current)^2 $\times resistance$ $[P = I^2 R]$ power, *P*, in watts, W potential difference, *V*, in volts, V current, *I*, in amperes, A (amp is acceptable for ampere) resistance, *R*, in ohms, Ω	The second equation comes from combining the first one with V=IR Remember that Power is a measure of how quickly the energy is used. A Watt is the same as a Joule per second or J/s.

4.2.4.2 Energy transfers in everyday appliances

Content	Additional Notes from Dr C
Everyday electrical appliances are designed to bring about energy transfers. The amount of energy an appliance transfers depends on how long the appliance is switched on for and the power of the appliance. Students should be able to describe how different domestic appliances transfer energy from batteries or ac mains to the kinetic energy of electric motors or the energy of heating devices. Work is done when charge flows in a circuit. The amount of energy transferred by electrical work can be calculated using the equation:	You should know that a light bulb uses more energy if you leave it on longer! Work done is back you will notice. It comes up all over the place from which we can infer that it is important.
$energy\ transferred = power \times time$ $[\ E = P\ t\ ]$ $energy\ transferred = charge\ flow \times potential\ difference$ $[\ E = Q\ V\ ]$ energy transferred, *E*, in joules, J power, *P*, in watts, W time, *t*, in seconds, s charge flow, *Q*, in coulombs, C potential difference, *V*, in volts, V	erWe already know this equation which comes directly from the definition of power. This one means that there is more energy transfered if the voltage is bigger or if there is more charge. It is an easy one to forget but is useful.
Students should be able to explain how the power of a circuit device is related to: • the potential difference across it and the current through it • the energy transferred over a given time. Students should be able to describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.	Every appliance in your home will have a power rating on it. A kettle is typically 3kW. A microwave 900W A lightbulb 10W

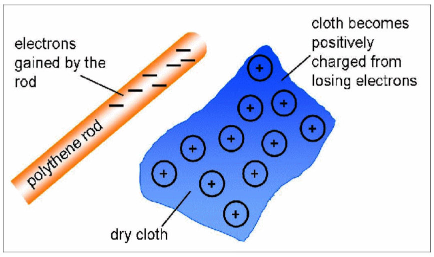
4.2.4.3 The National Grid

Content	Additional Notes from Dr C
The National Grid is a system of cables and transformers linking power stations to consumers.	How transformers work comes back later.

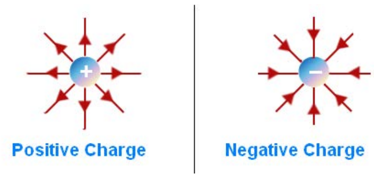
Content	Additional Notes from Dr C
Electrical power is transferred from power stations to consumers using the National Grid. Step-up transformers are used to increase the potential difference from the power station to the transmission cables then step-down transformers are used to decrease, to a much lower value, the potential difference for domestic use. Students should be able to explain why the National Grid system is an efficient way to transfer energy.	Power = current x voltage So to get a big power you need either a big current or a big voltage. If you have a big current then the wires will get hot and lots of energy will be lost therefore it is very inefficient so they transmit it at a very high voltage.

4.2.5 Static electricity (physics only)

4.2.5.1 Static charge

Content	Additional Notes from Dr C
When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material and on to the other. The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge. When two electrically charged objects are brought close together they exert a force on each other. Two objects that carry the same type of charge repel. Two objects that carry different types of charge attract. Attraction and repulsion between two charged objects are examples of non-contact force. Students should be able to: • describe the production of static electricity, and sparking, by rubbing surfaces • describe evidence that charged objects exert forces of attraction or repulsion on one another when not in contact • explain how the transfer of electrons between objects can explain the phenomena of static electricity.	Remember that everything is assumed to start electrically neutral so if you remove negative charge i.e. electrons it will become positively charged. Only the negative charge ever moves i.e. the electrons. 

4.2.5.2 Electric fields

Content	Additional Notes from Dr C
A charged object creates an electric field around itself. The electric field is strongest close to the charged object. The further away from the charged object, the weaker the field. A second charged object placed in the field experiences a force. The force gets stronger as the distance between the objects decreases. Students should be able to: • draw the electric field pattern for an isolated charged sphere • explain the concept of an electric field	This is a new bit so I bet it will be on the exam. The words make it sound complicated but it really isn't. It is just saying that the closer you are to the charge, the stronger the field is. 
• explain how the concept of an electric field helps to explain the non-contact force between charged objects as well as other electrostatic phenomena such as sparking.	Just like gravity, because there is an electric field it means that charges do not need to be touching to put a force on each other. This is the definition of a non-contact force. The other important one is the magnetic force and field.