Current

When electrons move through a wire we call it an electrical current. The electrons move as there is a potential difference. The larger the p.d. the higher the current flow or Coulombs per second.

$1A = 1Cs^{-1}$

$Q = It$

Charge = Current x time)

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Electrons

Electrons moving in a wire are a flow of charge of **$1.6 \times 10^{-19}C$** per electron.

This means that we can express the movement of a charge as…

$Q = It$ as **$Q = Ne$**

or the number of electrons moved and e is their charge

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Conductor

When a voltage is applied across a conductor delocalised electrons are attracted to the positive terminal.

The charges can move through the structure.

Metals are good conductors and have a low resistance or resistivity.

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Semi-conductor

The number of Charge carriers available for conduction increases with temperature.

Resistance decreases with temperature. Electrons can break free from the atoms of the semiconductor.

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Insulator

Electrons are firmly attached to atoms and cannot be moved through the conductor.

Wood or plastic are examples and they have a high resistance or resistivity.

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mA or µA

A current of 1 Ampere or 1A is very large and usually we work in mA (1×10^{-3}) or µA (1×10^{-6}) as a suffix.

Just make sure you don't forget to convert these in your calculations.

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Creating a PD

One way of separating charges is a chemical cell;

- Two chemical pastes are separated
- An anode is formed at one end (positive) & a cathode at the other (negative)
- When a wire is connected charges try and equalise pushing electrons through the wire.
- Thermal energy is lost inside the cell in the process. (Internal Resistance)

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Short Circuit

If you connect a wire across the terminals of a cell without a substantial resistance all the energy is discharged very quickly.

This can cause a massive heating effect burning out the wire and making the cell explode in some cases.

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Work on a Charge

1. To bring two like charges near each other work must be done.
2. To separate two opposite charges, work must be done.
3. Whenever work gets done, energy changes form.

Monkey example; Imagine two positive spheres in space and a monkey. Imagine that a small monkey does some work on one of the positive charges. He pushes the small charge towards the big charge;

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Electrical Potential or Volts

This is the amount of energy per unit of charge. It would be how many Joules each one is giving to each coulomb.

$$1V = 1JC^{-1}$$

A way to think of it in an electrical circuit is the energy rides around on the coulombs of charge which are delivered per second by the amp ($1A = 1Cs^{-1}$)

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Power 1

Energy in an electrical circuit is simply…

$$P = VI$$

This gives the unit of Js^{-1}

It is a measure of the rate of energy delivered to a component in the circuit by the charge carriers.

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Potential from a Cell

If placed in series to form a battery the P.D. of the cells adds up to provide a larger push or potential hill.

If placed in parallel to form a battery the P.D. of the battery is that of one cell but it can deliver a higher electrical current. 1.5V, 1.5V, 1.5V in series gives 1.5V over entire battery.

They are all the same steepness but have extra pathways.

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Power 2

The power delivered in a circuit is often thought of as a heating effect on the components. The power in a circuit to each component must add up to the entire power delivery from cell. If we use the formula V = IR we can form the P = VI equation into two other versions which can be helpful.

$$P = VI = I^2R = V^2/R$$

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eV in a telly!

We can think about moving an electron through a vacuum to in a telly. The way we do this is boil off electrons from filament lamp (low voltage) then pass then through a potential difference of 500V or similar. Then they gain in Kinetic energy…

$$KE = eV = qV = 0.5mv^2$$

This is a useful formula as it lets us work out the speed of the electrons.

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Energy in a Series Circuit

When we think of the energy that each component gets in a series circuit it has to share the energy per coulomb.

For example a cell of 9V with two bulbs in series will end up where each bulb has 4.5V pr $4.5JC^{-1}$.

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E = VIt

If a computer consumes power at a rate of 154W and is running for 1 hour how much energy flows…

Energy = Power x Time
Energy = 154W x 1 hour
Energy = 154W x 3600s
E = 154J/s x 3600s
E = 554400J
E = 554.4kJ

What current would be required by this computer on mains p.d. of 230V would be…

P = VI or P/V = 0.67A

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Ohms Law

The pd across a metallic conductor is proportional to the current through it, provided the physical conditions do not change. If we plot a graph of VI or IV the gradient is constant. If we plot V = IR or Y = MX then R is the gradient. If we plot V (1/R) = I then the gradient is 1/R. So we can work out the resistance from a simple experiment.

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Conduction Model

In a metal when an e.m.f. (electromotive force) is applied an electron is ripped from its local atom and then moves through the structure of the other adjacent atoms in a form of drift or current. Each electron gains some KE from the e.m.f. and jumps to another adjacent atom losing the KE and then repeats the process over and over….

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Resistivity Explained

There are two main principles at play here when we think about resistance. Both length and area can be looked at to see how the resistance of a conductor changes

To take both these ideas into account we think of a term called the resistivity instead of just resistance as a point value.

Resistivity does not change for a material and is a **constant** (at a constant temperature).

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Resistivity Formula

$$\rho = RA/L$$

R = Resistance in ohms Ω
ρ = Resistivity in ohm meters Ω m

A = Cross sectional area in meters squared m^2 (cannot use mm!)

l = length in meters m

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Area of a Conductor

In exam questions they will often ask you about the volume or cross sectional area.

Make sure you can work out that **$A = \pi r^2$** which is harder in meters than you might think.

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Resistivity Values

Look for this range of values when you have worked out an answer it might show you if you have made a conversion mistake…

Metals: Copper 1.7×10^{-8} Ωm

Semiconductor: Germanium (pure) 0.6 Ωm

Insulator: Glass 1.7×10^{12} Ωm

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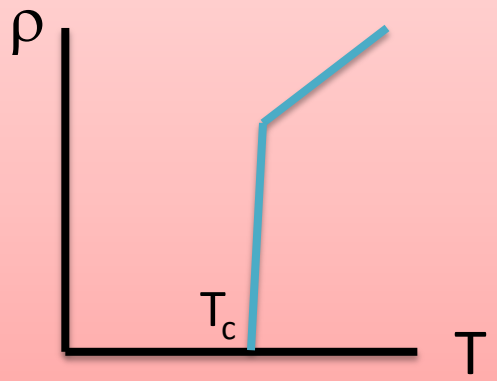
Superconductivity

This is the property of a material which is at or below a critical temperature Tc where it has zero resistivity. Learn the resistivity graph.



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Properties of Superconductor

- Zero resistance below Tc / no heating effect / no p.d. with current flowing.
- material loses the effect above the critical temperature Tc.
- If Tc is above 77K (-196 C) it's a **high temperature** superconductor
- The highest Tc max = 150 K – 123C

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Metals

- resistance increases with temperature
- positive ions vibrate more
- conduction electrons movement is impeded
- positive temperature coefficient
- Low resistivity

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Intrinsic Semiconductors

- resistance decreases with temperature
- more charge carriers become available
- negative temperature coefficient
- much larger change in resistance than with metals
- thermistors used as temperature sensitive component in a sensor

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Semiconductor Conduction

A model of conduction called "hopping" is relevant for some materials. It is a form of ionic conductivity where ions (oxygen ions) "hop" between point defect sites in the crystal structure. The probability of point defects in the crystal lattice increases as temperature increases, hence the "hopping" is more likely to occur at higher temperatures. **(this is more advanced that you need at AS)**

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Temperature Sensors

If we setup a Thermistor in a potential divider circuit we can see that the P.D. dropped across it changes as the temperature changes.

A common use is the glass heat sensor in a car or the temperature sensor in a conventional oven. The rise in current turns on/off the oven or fan and heater.

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Diodes and LED

Diodes are simply made of two semiconductor halves made from a silicon lattice with an **impurity** which will enable it to conduct. We often refer to these types of materials as intrinsic semiconductors.

In fact we "dope" one half with a positive impurity and one half with a negative half. This means the diode conducts on one directly only.

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Diodes Graphing

When voltage is in **forward bias** the resistance is large below 0.7V as **band gap is large**. Current is in mA.

When voltage is **above 0.7** the band gap is closed and the **diode conducts freely** and resistance is low.

When in reverse bias direction the current flow is **very small mA** as band gap increases.

Above the breakdown voltage V_b the band gap is very large the PN junction breaks down permanently.

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Circuits Equations

We should be able to use the following equations from GCSE and AS-Level interchangeably as they all relate to the same symbols.

$P = VI$
$P = Et$
$V = IR$
$P = I^2R$
$P = V^2/R$
$Q = It$
$E = Vit$
$E = VQ$

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Potential Dividers

If we wish to look at the current flow through a device it is often useful to setup a potential divider circuit.

A good side to this is that you can reduce the p.d. dropped across a device to zero.

The downside is you waste more thermal energy as a current is always flowing through the variable resistor part of the circuit.

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