Physics Knowledge Organiser

P4 - Electric circuits

Static charge (Physics Only)

Every atom contains particles with an electric charge: protons and electrons. The electrons can be transferred from one material to another. When certain insulating materials are rubbed together, they both become charged because electrons are transferred from one material to the other.

- The material gaining electrons becomes negatively charged
- The material losing electrons becomes positively charged
- The size of the charge one each material is the same magnitude, but opposite in direction (+ vs -)

Electrically charged objects affect other charged objects. Like charges repel, whereas oppositely charged objects are attracted to each other. This is a **non-contact force**.

If there is a big enough difference in charge between two places, sometimes the charge can seem to 'jump'. This is seen as a spark. The charge does not, in fact, jump, but flows through the air, heating the air up enough to make it glow. This neutralises the charged objects, so is known as a **discharge**. In fact, this is the basic idea behind how lightning works.

Electric fields (Physics Only)

Any charged object produces an **electric field** around it, which extends in all directions away from the object. Other charged objects in this electric field are affected by it – either attracted or repelled as described above. The electric field gets weaker with distance from the charged object, which is obvious when you look at the diagram, right, because the **field lines** (the arrows) spread out going away from the charged object.

These field lines are not 'real things', but they represent the electric field. If you look at how many lines pass through a certain area, you can get a sense of the strength of the electric field. The more lines pass through the area, the stronger the field. When we say a field is stronger, it means it will exert more force on other charged objects. This concept of the electric field helps explain why electric attraction/repulsion is a non-contact force: the objects don't need to touch, but do need to be within each other's electric fields.
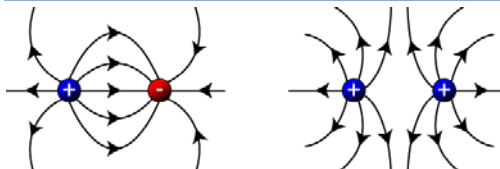

This diagram shows how field lines cause attraction between opposite charges and

repulsion between like charges. Again, they don't need to touch to exert these forces on each other.

Key Terms	Definitions
Electric charge	Just a positive or negative charge!
Static	Not moving.
Insulator	Material that does NOT conduct electric current
Attraction	Being pulled together
Repulsion	Being pushed apart
Discharge	Movement of a charge from a charged object, making it neutral
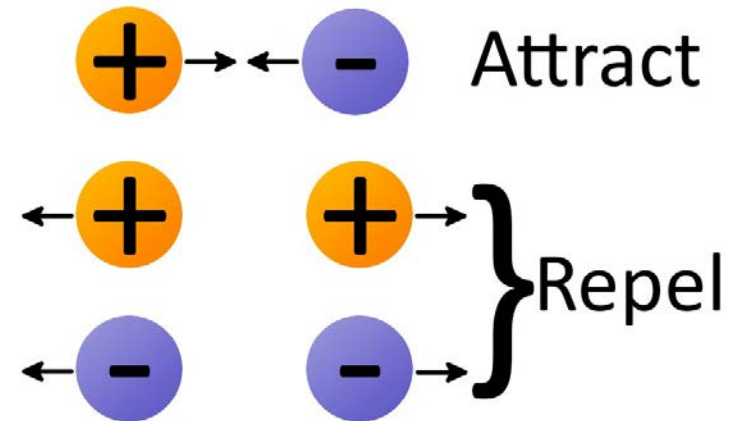
A charged sphere on its own (*isolated*). The arrows point the other way if the object is negatively charged. The rhombuses show how more lines cut through the same area if you are closer to the charged object. This indicates that the field is stronger closer to the charged object.
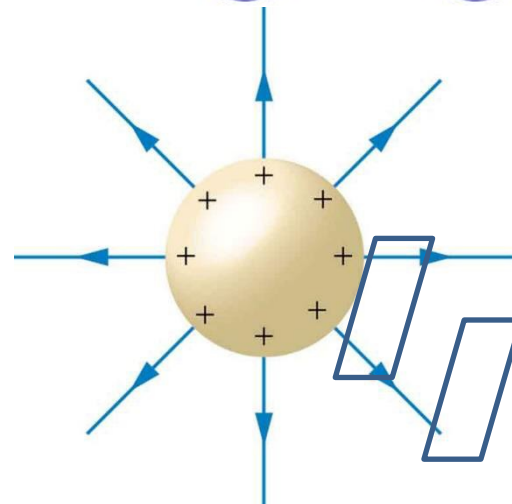
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Series and parallel circuits

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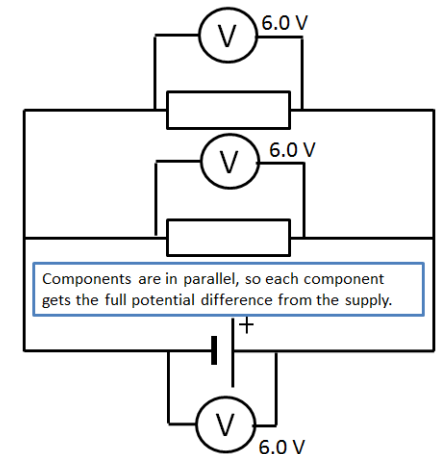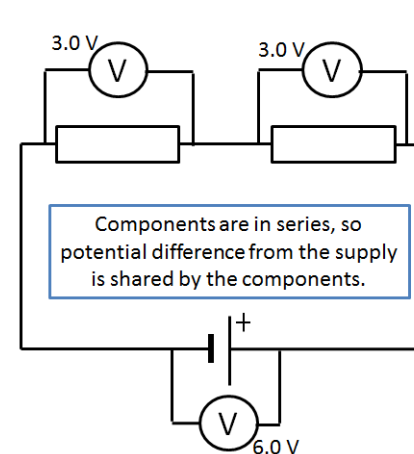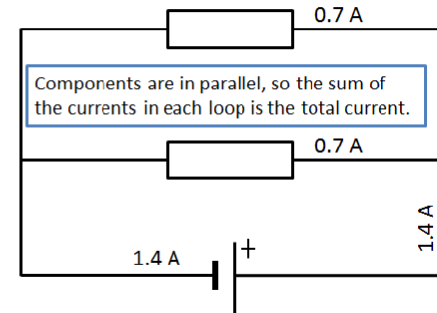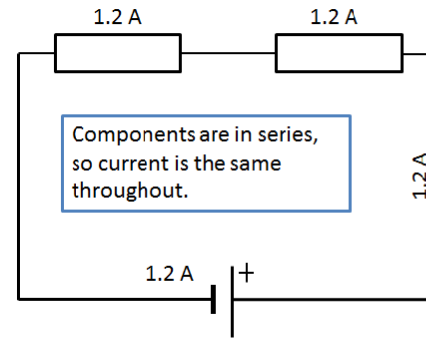
The quantities of resistance, current and potential difference behave differently in components connected in series compared to components connected in parallel. Study the table and diagrams carefully.

These resistors are **in series** with in each other

These resistors are **parallel** to each other
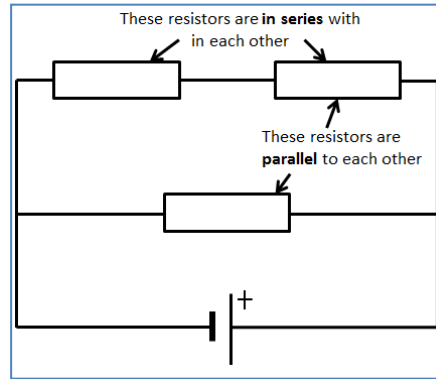
Key Terms	Definitions
Series	Components connected one after another in a closed loop.
Parallel	Components connected in different loops of a circuit.
Resistor	An electrical component that regulates current in a circuit. Bear in mind, all electrical components have **resistance**, so are resistors in some 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

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.

1.2 A   1.2 A

Components are in series, so current is the same throughout.

1.2 A

1.2 A

0.7 A

Components are in parallel, so the sum of the currents in each loop is the total current.

0.7 A

1.4 A

1.4 A

3.0 V   3.0 V

Components are in series, so potential difference from the supply is shared by the components.

6.0 V

6.0 V

Components are in parallel, so each component gets the full potential difference from the supply.

6.0 V

6.0 V

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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

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.
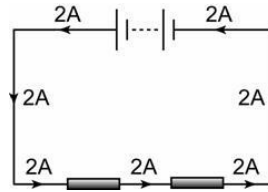

Current, resistance and potential difference

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 do no work (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
* $Q = It$	Q = charge flow (coulombs, C) I = current (amperes, A) t = time (seconds, s)
* $V = IR$	V = potential difference (volts, V) I = current (amperes, A) R = resistance (ohms, Ω)
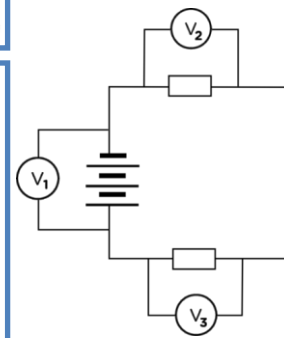
Look how the voltmeters are added **across** the components to measure the potential difference across them.

switch (open)	bulb
switch (closed)	fuse
cell	voltmeter
battery	ammeter
diode	thermistor
resistor	
variable resistor	LDR
LED	

Yes, you need to learn these symbols.

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Equation	Meanings of terms in equation
$V = I R$ *	V = potential difference (volts, V) I = current (amperes, A) R = resistance (ohms, Ω)

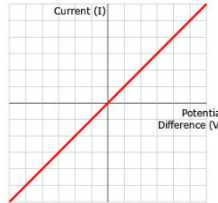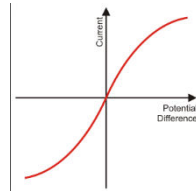## Ohmic conductors

When a conductor obeys Ohms law we call it an Ohmic conductor. For this to happen the temperature needs to remain constant. The current is directly proportional to the potential difference across the resistor. Doubling the energy into the resistor causes the current going through the resistor to flow twice as fast.

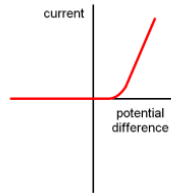Because of this the resistance remains constant and we can use the equation V=IR

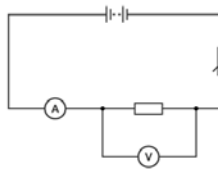The graph of a fixed resistor is an example of a component which obeys Ohms law.

The graph shows the resistor is obeying Ohm's Law. The straight line tells us the current is proportional to the potential difference across the resistor.

Non-Ohmic conductors

Lamps, diodes, thermistors and LDR's are examples on non-ohmic conductors. Their resistance is not constant; it changes with current through the component.

Filament lamps:

As the temperature of a filament lamp increases, the resistance increases. The higher temperature increases the vibrations of the ions in the filament which makes it harder for the electrons to get past.

Diode:

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

Thermistor:

The resistance of a thermistor decreases as the temperature increases

LDR:

The resistance of an LDR decreases as light intensity increases.

Filament lamp

A diode

A circuit diagram for the required practical

Applications of LDR's and thermistors

LDR's can be used in sensing circuits to switch on the lights when it gets dark

Thermistors can be used is circuits to turn on the heating when the temperature drops below a certain level.

Investigating the relationship between current and potential difference

To investigate the relationship between current and potential difference for a resistor, bulb and diode.

Method

1. Connect the circuit as shown in the diagram.

2. Ensure that the power supply is set to zero at the start.

3. Record the reading on the voltmeter and ammeter.

4. Use the variable resistor to alter the potential difference.

5. Record the new readings on the voltmeter and ammeter.

6. Repeat steps three to four, each time increasing the potential difference slightly.

7. Reverse the power supply connections and repeat steps two to six.

8. Plot a graph of current against potential difference for each component.

9. Repeat the experiment but replace the fixed resistor with a bulb.