Chapter 4: Electric circuits

Knowledge organiser

Charge

An atom has no **charge** because it has equal numbers of positive protons and negative electrons.

When electrons are removed from an atom it becomes *positively* charged. When electrons are added to an atom it becomes *negatively* charged.

Static charge

Insulating materials can become charged when they are rubbed with another insulating material. This is because electrons are transferred from one material to the other. Materials that gain electrons become negatively charged and those that lose electrons become positively charged.

Positive charges do not usually transfer between materials.

Electric charge is measured in coulombs C.

Sparks

If two objects have a very strong electric field between them, electrons in the air molecules will be strongly attracted towards the positively charged object. If the electric field is strong enough, electrons will be pulled away from the air molecules and cause a flow of electrons between the two objects – this is a **spark**.

Drawing electric fields

A charged object creates an **electric field** around itself.

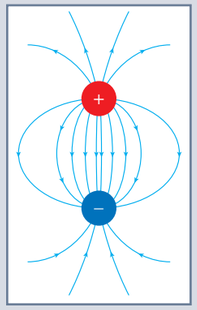
If a charged object is placed in the electric field of another charged object it experiences **electrostatic force**. This means that the two charged objects exert a non-contact force on each other:

- like charges repel each other
- opposing charges attract each other.

The electric field, and the force between two charged objects, gets stronger as the distance between the objects decreases.

Drawing electric fields

Electric fields can be represented using a diagram with field lines. These show the direction of the force that a small positive charge would experience when placed in the electric field.



When drawing electric fields, make sure:

- field lines meet the surface of charged objects at 90°
- arrows always point away from positive charges and towards negative charges.

Resistance

When electrons move through a circuit, they collide with the ions and atoms of the wires and components in the circuit. This causes **resistance** to the flow of charge.

The unit of resistance is the ohm (Ω).

A long wire has more resistance than a short wire because electrons collide with more ions as they pass through a longer wire.

The resistance of an electrical component can be found by measuring the current and potential difference:

$$\text{potential difference (V)} = \text{current (A)} \times \text{resistance (Ω)}$$

$$V = IR$$

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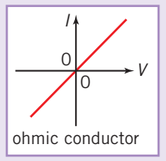
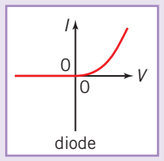
Current-potential difference graphs

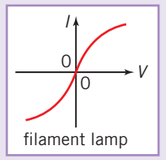
A graph of current through a component against the p.d. across it (I–V graph), is known as the component characteristic.



Current is directly proportional to the p.d. in an ohmic conductor at a constant temperature. The resistance is constant.



The current through a diode only flows in one direction – called the forward direction. There needs to be a minimum voltage before any current will flow.



As more current flows through the filament, its temperature increases. The atoms in the wire vibrate more, and collide more often with electrons flowing through it, so resistance increases as temperature increases. The resistance of a thermistor decreases and temperature increases. The resistance of a light dependent resistor (LDR) decreases as light intensity increases.

The resistance of an ohmic conductor can be found by calculating the gradient at that point and taking the inverse:

$$\text{resistance} = \frac{1}{\text{gradient}}.$$

Electric current

Electric current is when **charge** flows. The charge in an electric circuit is carried by electrons.

The unit of current is the ampere (amp, A).

$$1 \text{ ampere} = 1 \text{ coulomb of charge flow per second}$$

$$\text{Charge (C)} = \text{current (A)} \times \text{time (s)}$$

In circuit diagrams, current flows from the positive terminal of a cell or battery to the negative terminal. This is known as conventional current.

In a single closed loop, the current has the same value at any point in the circuit.

Metals are good conductors of electricity because they contain delocalised electrons, which are free to flow through the structure.

Potential difference

Potential difference (p.d.) is a measure of how much energy is transferred between two points in a circuit. The unit of potential difference is the volt (V).

- The p.d. across a component is the work done on it by each coulomb of charge that passes through it.
- The p.d. across a power supply or battery is the energy transferred to each coulomb of charge that passes through it.

For electrical charge to flow through a circuit there must be a source of potential difference.

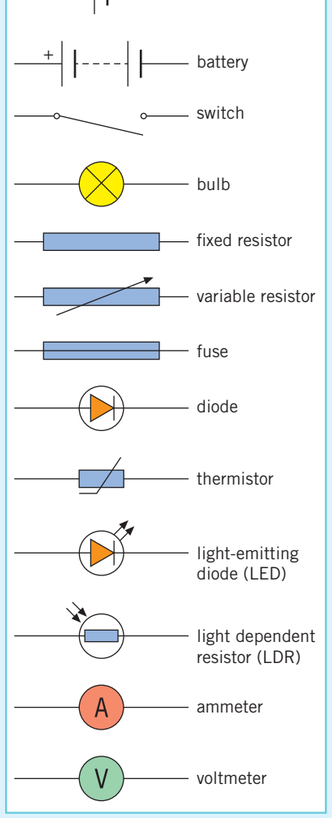
$$\text{Potential difference (V)} = \text{energy transferred (J)} / \text{charge (C)}$$

Key terms

Make sure you can write a definition for these key terms.

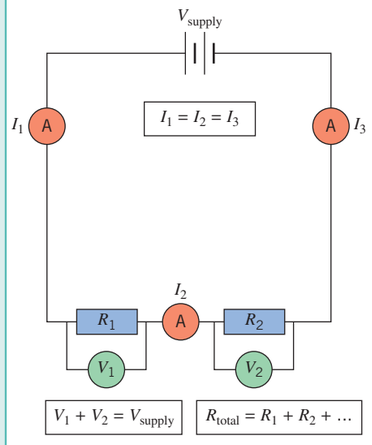
ampere
charge
coulomb
current
electric field
electrostatic force
LDR
parallel
potential difference
resistance
series
static
thermistor

Circuit components



Series circuits

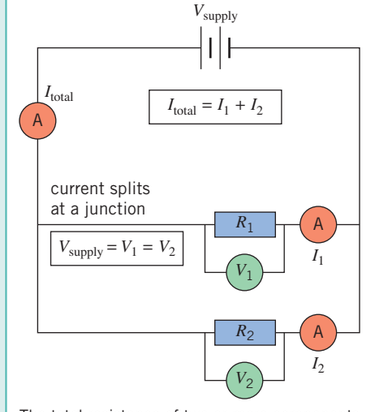
In a series circuit, the components are connected one after the other in a single loop. If one component in a series circuit stops working the whole circuit will stop working.



Components with a higher resistance will transfer a larger share of the total p.d. because $V = IR$ (and current is the same through all components).

Parallel circuits

A parallel circuit is made up of two or more loops through which current can flow. If one branch of a parallel circuit stops working, the other branches will not be affected.



The total resistance of two or more components in parallel is always less than the smallest resistance of any branch. This is because adding a loop to the circuit provides another route for the current to flow, so more current can flow in total even though the p.d. has not changed. Adding more resistors in parallel decreases the total resistance of a circuit.

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Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	P4 questions	Answers
1	How does a material become charged?	becomes negatively charged by gaining electrons and becomes positively charged by losing electrons
2	What will two objects carrying the same type of charge do if they are brought close to each other?	repel each other
3	What is an electric field?	region of space around a charged object in which another charged object will experience an electrostatic force
4	What happens to the strength of an electric field as you get further from the charged object?	it decreases
5	What is electric current?	rate of flow of charge
6	What units are charge, current, and time measured in?	coulombs (C), amperes (A), seconds (s) respectively
7	What is the same at all points when charge flows in a closed loop?	current
8	What must there be in a closed circuit so that electrical charge can flow?	source of potential difference (p.d.)
9	Which two factors does current depend on and what are their units?	resistance in ohms (Ω), p.d. in volts (V)
10	What happens to the current if the resistance is increased but the p.d. stays the same?	current decreases
11	What is an ohmic conductor?	conductor where current is directly proportional to the voltage so resistance is constant (at constant temperature)
12	What happens to the resistance of a filament lamp as its temperature increases?	resistance increases
13	What happens to the resistance of a thermistor as its temperature increases?	resistance decreases
14	What happens to the resistance of a light-dependent resistor when light intensity increases?	resistance decreases
15	What are the main features of a series circuit?	same current through each component, total p.d. of power supply is shared between components, total resistance of all components is the sum of the resistance of each component
16	What are the main features of a parallel circuit?	p.d. across each branch is the same, total current through circuit is the sum of the currents in each branch – total resistance of all resistors is less than the resistance of the smallest individual resistor

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