

Electricity

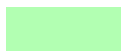
Specification 8463 · AQA

Free edition

Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Electric current

- the rate of flow of electrical charge, in amperes (A).

Define Resistance

- how difficult it is for charge to flow through a component, in ohms (Ω).

Define Series circuit

- components joined one after another in a single closed loop.

Define Direct potential difference (dc)

- always in the same direction, so charge flows one way only.

Define Live wire

- brown; carries the alternating potential difference from the supply.

Define Earth wire

- green and yellow stripes; safety wire that stops the appliance becoming live.

Define National Grid

- a system of cables and transformers linking power stations to consumers.

Define Step-down transformer

- decreases the potential difference to a much lower value for domestic use.

Define Electric field

- the region around a charged object in which another charged object feels a force.

Define Potential difference

- the energy transferred per unit charge, in volts (V). ("Voltage" gains credit, but use potential difference.)

Define Ohmic conductor

- a component whose resistance stays constant, so current is directly proportional to potential difference (at constant temperature).

Define Parallel circuit

- components on separate branches, each connected across the supply.

Define Alternating potential difference (ac)

- repeatedly changes direction, so the current alternates.

Define Neutral wire

- blue; completes the circuit.

Define Power

- the energy transferred per second, in watts (W). An appliance's **power rating** is the power it transfers when working normally.

Define Step-up transformer

- increases the potential difference for transmission.

Define Static electricity

- charge that builds up on an insulator and stays there.

2.1 Current, potential difference and resistance

2.1.1 Standard circuit diagram symbols

Circuit diagrams use **standard symbols**. You must be able to **draw and interpret** them. Draw wires as straight lines with right-angled corners, and never leave a gap in a wire.

Component	Symbol	What it does
Cell	Long thin line and short thick line	Provides the pd (long line = positive)
Battery	Two or more cells end to end	A larger pd than one cell
Switch (open)	Two dots, line lifted off one	Breaks the circuit — no current
Switch (closed)	Two dots joined by a line	Completes the circuit
Fixed resistor	Plain rectangle	Fixed opposition to current
Variable resistor	Rectangle with a diagonal arrow through it	Resistance can be changed, so current can be changed
Lamp (filament lamp)	Circle with a cross inside	Transfers energy to light and heat
Ammeter	Circle with a capital A	Measures current; connect in series
Voltmeter	Circle with a capital V	Measures pd; connect in parallel across the component
Fuse	Rectangle with a line through it	Melts to break the circuit if the current is too large
Diode	Triangle pointing at a straight line	Current flows one way only
LED	Diode symbol with two arrows pointing away	Emits light when current flows forwards
Thermistor	Rectangle with a bent line across it	Resistance falls as temperature rises
LDR	Rectangle in a circle with two arrows pointing in	Resistance falls as light intensity rises

Standard circuit symbols and what each component does



cell

supplies a potential difference



battery

two or more cells joined in series



switch (open)

no current can flow



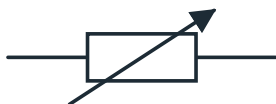
switch (closed)

current can flow



fixed resistor

resistance stays constant



variable resistor

resistance can be changed



filament lamp

resistance rises as it gets hotter



ammeter

measures current, A connect in series



voltmeter

measures p.d., V connect in parallel



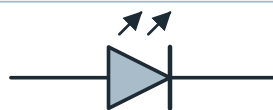
fuse

melts if the current is too high



diode

current flows one way only



LED

light-emitting diode emits light when on



thermistor

resistance falls as temperature rises



LDR

light-dependent resistor

2.1.2 Electrical charge and current

- For electrical charge to flow through a **closed circuit**, the circuit must include a **source of potential difference** (a cell, battery or mains supply).
- Electric current is a flow of electrical charge.** The size of the current is the **rate of flow of charge**.
- A current has the same value at any point in a single closed loop.

WATCH OUT

Current is not used up as it goes round a circuit. An ammeter before a lamp and one after it read exactly the same. What is transferred in the lamp is **energy**, not charge — every coulomb leaving the cell returns to it. If one bulb in a series circuit looks brighter, it is not because it "used up the current"; the current is the same through every component in series.

ANALOGY

The rope loop (and water in pipes). A loop of rope runs through everyone's hands: pulling it is the **potential difference**, the rope moving is the **current**, gripping it tightly is the **resistance**. The rope moves at the same speed everywhere, just as current is the same everywhere in a single loop. The water version is the same idea — pump, flow rate, pressure difference, narrow pipe. Both break down in the same place: water can spill from an open pipe, but charge is never lost.

2.1.3 Current, resistance and potential difference

- The **current (I)** through a component depends on both the **resistance (R)** of the component and the **potential difference (V)** across it.
- The **greater the resistance**, the **smaller the current** for a given potential difference.

WATCH OUT

Potential difference is across, current is through. A voltmeter goes in parallel, across the ends of a component, because it compares the energy per coulomb on either side. An ammeter goes in series, because the charge must pass through it to be counted. "The potential difference through the resistor" or "the current across the lamp" loses marks.

2.1.4 Resistors

- For **some** resistors R stays constant; in **others** it changes as the current changes.
- The current through an **ohmic conductor at constant temperature** is **directly proportional** to the potential difference across it, so resistance stays constant.
- The resistance of **lamps, diodes, thermistors and LDRs** is **not constant**; it changes with the current through the component.

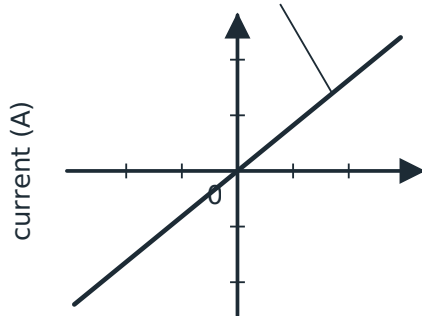
I-V characteristics — the shapes you must know

Component	Shape of the I-V graph	Why
Ohmic conductor (resistor at constant temperature)	Straight line through the origin, both directions	Resistance constant, so $I \propto V$
Filament lamp	S-shaped curve through the origin that gets shallower at higher V	Current heats the filament; resistance increases as temperature increases
Diode	Almost zero current one way; current rises steeply after a small forward pd	Current flows in one direction only ; very high resistance in the reverse direction

I-V characteristics of an ohmic conductor, a filament lamp and a diode

ohmic conductor

straight line through 0

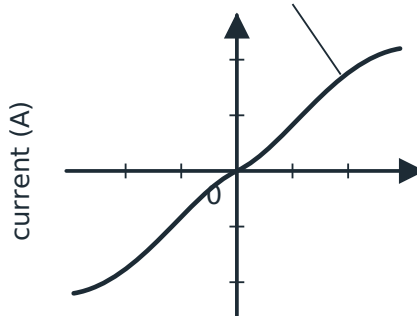


potential difference (V)

- at a constant temperature
- current is directly proportional to p.d.
- resistance stays constant
- e.g. a fixed resistor

filament lamp

curve gets shallower

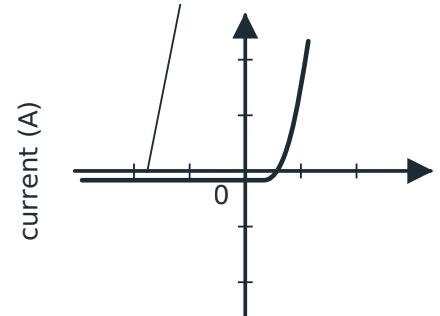


potential difference (V)

- as the current rises the filament gets hotter
- its resistance increases, so the graph is not linear
- same shape both ways

diode

no current in reverse



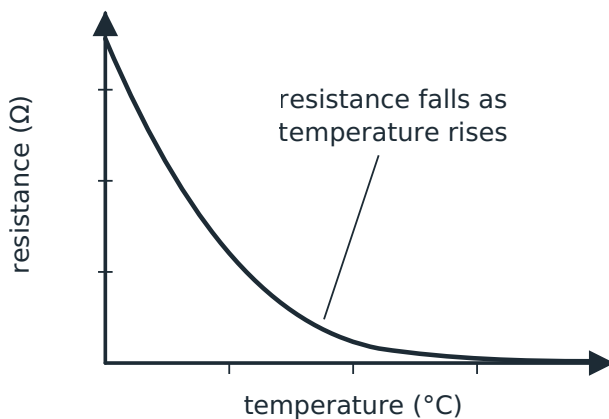
potential difference (V)

- current flows in one direction only
- in reverse the resistance is very high, so almost no current flows

- **Thermistor** — resistance **decreases as temperature increases**. Used in a thermostat: as a room cools the thermistor's resistance rises, the current falls, and the control circuit switches the heater on.
- **LDR** — resistance **decreases as light intensity increases**. Used to switch street lights on at dusk: as light fades the resistance rises and the circuit triggers the lamp.
- To **measure the resistance of a component**: ammeter in series, voltmeter in parallel across it, vary the current with a variable resistor, then use $R = V \div I$.
- Use graphs to decide whether an element is **linear** (straight line) or **non-linear** (curved).

How the resistance of a thermistor and of an LDR changes, and where each is used

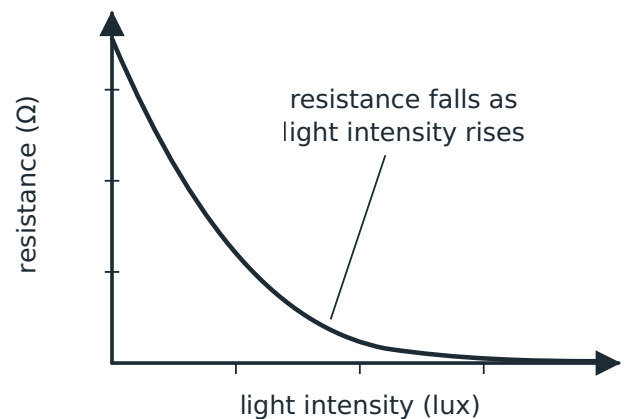
thermistor



Application: thermostat

A thermostat keeps a room at a set temperature. When the room is cold the thermistor has a high resistance. As the room warms up its resistance falls and the circuit switches the heater off.

light-dependent resistor (LDR)



Application: automatic night light

An outside light switches itself on when it gets dark. In daylight the LDR has a low resistance. As it gets dark the resistance rises and the circuit switches the lamp on.

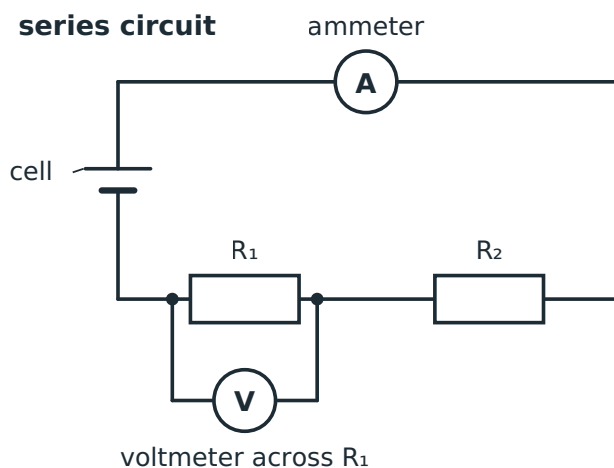
2.2 Series and parallel circuits

There are two ways of joining components: **in series** and **in parallel**. Some circuits include both.

	Series	Parallel
Current	The same current through each component	The total current is the sum of the currents through the separate components
Potential difference	The supply pd is shared between the components	The pd across each component is the same
Total resistance	$R_{\text{total}} = R_1 + R_2$ — always larger than either resistor	Less than the resistance of the smallest individual resistor
If one component breaks	The whole circuit stops working	The other branches keep working

Series and parallel circuits compared

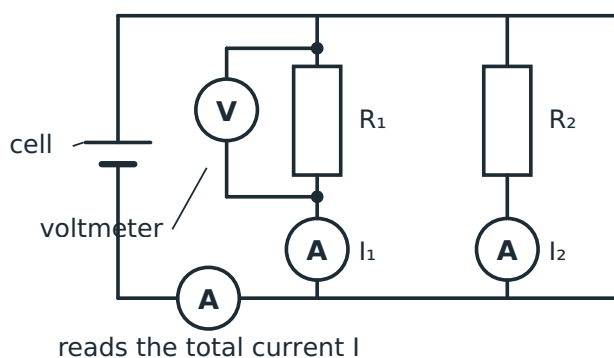
series circuit



In series

- the current is the same through every component: $I_1 = I_2 = I_3$
- the potential differences add up to the p.d. of the supply: $V = V_1 + V_2$
- the resistances add up: $R_{\text{total}} = R_1 + R_2$
- adding a resistor in series increases the total resistance, so the current gets smaller

parallel circuit



In parallel

- the potential difference across each branch is the same as the supply p.d.: $V = V_1 = V_2$
- the branch currents add up to the total current: $I = I_1 + I_2$
- the total resistance of two resistors is less than the resistance of the smallest resistor
- adding a resistor in parallel gives the current more paths, so the total resistance falls and the total current gets bigger

- **Why series increases resistance:** the extra resistor adds more opposition into the same single path, so for the same supply pd the current falls.
- **Why parallel decreases resistance:** the extra resistor gives charge an **extra route**, so the total current from the supply rises — and a bigger current for the same pd means a smaller total resistance.
- dc series circuits for measurement and testing: an ammeter, a variable resistor and the component under test in one loop lets you set the current precisely and test one component at a time.
- You are **not required** to calculate the total resistance of two resistors in parallel.

ANALOGY

Series vs parallel — supermarket checkouts. In **series** every shopper passes through every till in turn: same current everywhere, queuing shared out, and an extra till slows the whole journey. In **parallel** shoppers split between tills: each till faces the same shop (same pd), the flows add, and opening another till speeds things up. It breaks down because shoppers choose their queue, whereas charge divides according to each branch's resistance.

2.3 Domestic uses and safety

2.3.1 Direct and alternating potential difference

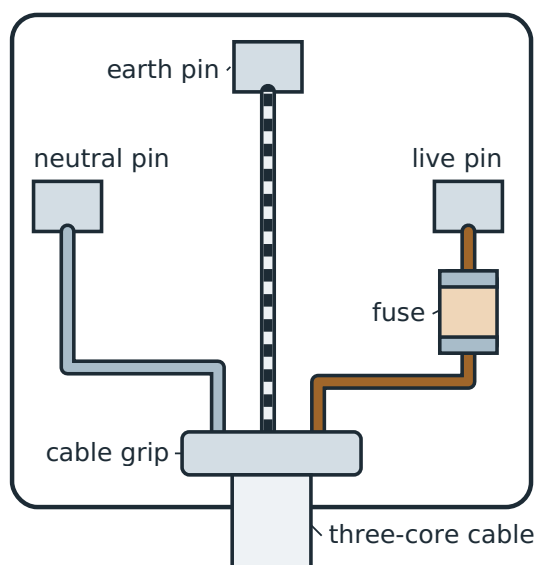
- **Direct potential difference (dc)** is always in the **same direction**, so the current flows one way only. Cells and batteries give dc.
- **Alternating potential difference (ac)** repeatedly **changes direction**, so the current alternates. Mains electricity is an **ac supply**.
- In the United Kingdom the domestic supply has a **frequency of 50 Hz** and is about **230 V**.

2.3.2 Mains electricity

Most appliances are connected to the mains using **three-core cable**. The insulation on each wire is colour coded.

Wire	Colour of insulation	Potential difference	Job
Live	Brown	About 230 V relative to earth, alternating	Carries the alternating potential difference from the supply
Neutral	Blue	At or close to 0 V (earth potential)	Completes the circuit
Earth	Green and yellow stripes	0 V	Safety wire that stops the appliance becoming live; carries a current only if there is a fault

Inside a three-pin plug: live, neutral and earth



-  live wire — brown
-  neutral wire — blue
-  earth wire — green and yellow stripes

Why the live wire is dangerous even when a switch is open

- A switch only breaks the circuit. It does not disconnect the live wire from the supply, so the live wire is still at about 230 V compared with earth (0 V).
- If you touch the live wire you complete a path from the live wire to earth. A current flows through your body and you get an electric shock, which can be fatal.
- Any connection between the live wire and earth causes a very large current, which can melt the fuse and can start a fire.
- The earth wire and the fuse work together: a fault current flows to earth, the fuse in the live wire melts and the appliance is cut off from the live supply.

wire	job it does	potential difference
live (brown)	carries the alternating potential difference from the supply to the appliance	about 230 V compared with earth
neutral (blue)	completes the circuit — it carries the current back to the supply	at or close to 0 V (earth potential)
earth (green and yellow stripes)	a safety wire that stops the metal case of the appliance becoming live; it carries a current only if there is a fault	0 V

- A live wire is dangerous even when a switch in the mains circuit is open. Opening the switch stops the current, but the live wire on the supply side is **still at about 230 V**. Touching it connects the live wire to earth through your body (you are at 0 V), so a large potential difference acts across you and a current passes through you to earth — a severe electric shock.
- Any connection between the live wire and earth is dangerous: a large current flows, which can be fatal and can cause enough heating to start a fire.
- If a fault connects the live wire to a metal casing, the earth wire carries the fault current away and the large current melts the **fuse**, disconnecting the live wire.

2.4 Energy transfers

2.4.1 Power

The power transferred in any circuit device depends on the **potential difference across it** and the **current through it**, and on the energy transferred over time.

NOTE

The kilowatt-hour is not named in the specification, but "cost of electricity" contexts do appear in questions. The equation you need is $E = P t$, in **joules, watts and seconds**.

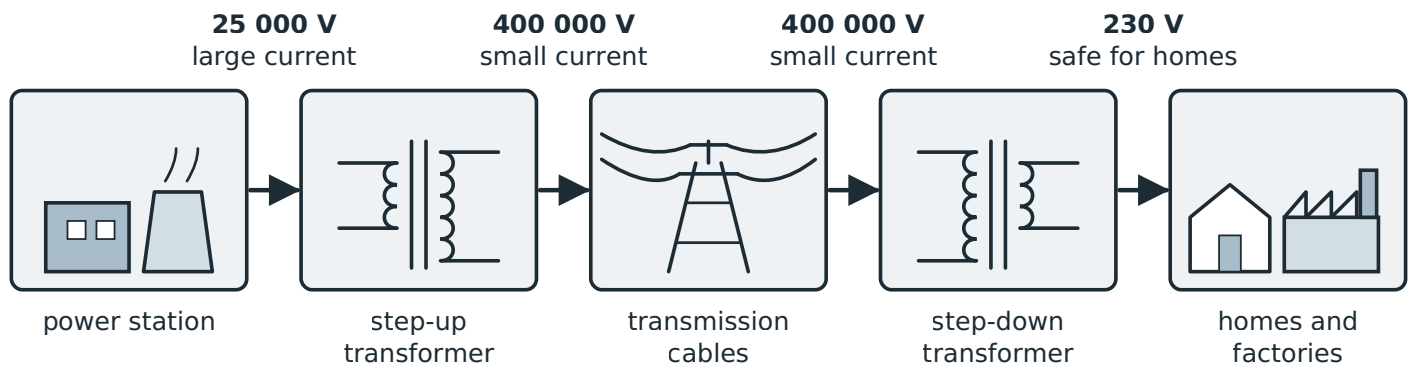
2.4.2 Energy transfers in everyday appliances

- Appliances are designed to bring about **energy transfers**. The energy transferred depends on how long the appliance is on for and on **its power**.
- They transfer energy from **batteries or the ac mains** to the **kinetic energy store of electric motors** (fan, washing machine, food mixer) or to **heating devices** (kettle, iron, oven).
- **Work is done when charge flows in a circuit** — that is how energy gets from the supply to the component.

2.4.3 The National Grid

- The **National Grid** is a system of **cables and transformers** linking **power stations to consumers**.
- Electrical power is transferred from power stations to consumers using the National Grid.
- **Step-up transformers** increase the potential difference from the power station to the transmission cables.
- **Step-down transformers** then decrease the potential difference to a much lower value for **domestic use**.
- **Why this is efficient:** the power transferred is $P = VI$, so for the same power a higher potential difference means a smaller current. The energy wasted heating the cables is given by $P = I^2 R$ — because it depends on the **square** of the current, a small current wastes far less energy. Step-down transformers then bring the pd back to a safe value for homes.

The National Grid: step-up and step-down transformers



Reducing the energy dissipated in the cables

- The transmission cables have resistance, so some energy is dissipated by heating as current flows.
- A transformer does not change the power that is transferred: $P = VI$ stays the same. So if the p.d. is stepped up, the current is stepped down.
- The power wasted in the cables is $P = I^2R$, so it depends on the square of the current: halving the current cuts the wasted power to a quarter.
- A high potential difference and a low current therefore make the National Grid an efficient way of transferring energy.

$$P = I^2 R$$

P = power wasted in the cables, watts (W)

I = current in the cables, amperes (A)

R = resistance of the cables, ohms (Ω)

Stepping the potential difference up 16 times steps the current down 16 times, so the power wasted in the cables falls by $16^2 = 256$ times.

ANALOGY

The National Grid — buckets or tankers. Deliver the same water either as thousands of buckets sloshing down a corridor (big current, lots spilled) or as a few sealed tankers (small current, almost nothing lost). The spillage is the energy wasted heating the cables — though nothing is truly lost: it is transferred to the thermal store of the surroundings.

2.5 Static electricity PHYSICS ONLY

2.5.1 Static charge **PHYSICS ONLY**

- **PHYSICS ONLY** When certain **insulating materials** are rubbed together they become **electrically charged**. Negatively charged **electrons** are rubbed off one and on to the other: the material that **gains** electrons becomes **negatively charged**, the one that **loses** them is left with an **equal positive charge**. Only electrons move.
- **PHYSICS ONLY** Example: rub a polythene rod with a cloth — the rod gains electrons and becomes negative, the cloth becomes positive.
- **PHYSICS ONLY** Two charged objects brought close together **exert a force on each other: same charges repel, different charges attract**. These are **non-contact forces**. **PHYSICS ONLY Evidence:** a charged rod attracts small pieces of paper without touching them; a charged balloon sticks to a wall; two charged rods on threads swing apart or together before they meet. **PHYSICS ONLY Sparking:** as charge builds up, the potential difference between the object and an earthed object grows. If it gets large enough, electrons jump the air gap — the air conducts briefly and a spark is seen and heard.

2.5.2 Electric fields **PHYSICS ONLY**

- **PHYSICS ONLY** A charged object creates an **electric field** around itself. The field is **strongest close to** the object and gets **weaker** further away.
- **PHYSICS ONLY** A second charged object placed in the field experiences a force, and that force gets stronger as the distance between the objects decreases.
- **PHYSICS ONLY** Field pattern for an isolated charged sphere: straight radial lines, evenly spaced all round the sphere, arrows pointing **away** from a positive sphere and **towards** a negative one. Lines closer together near the sphere show the stronger field. **PHYSICS ONLY Explaining the non-contact force:** the objects never touch, but each sits in the other's field, and an object in a field feels a force — the closer they are, the stronger the field and the greater the force. **PHYSICS ONLY Explaining sparking:** a big build-up of charge makes a very strong field, which pulls electrons off atoms in the air, so the air stops insulating and a spark passes.