Edexcel GCSE Physics

Your notes

Current, Potential Difference & Resistance

Contents

Atomic Structure

Your notes

Protons, Neutrons & Electrons

- Atoms are the building blocks of **all matter**
- They are incredibly small - for instance, about one hundred million atoms could fit side by side across your thumbnail
- Atoms have a tiny, dense **nucleus** at their centre, with **electrons** orbiting around the nucleus
- The nucleus is made up of **protons** and **neutrons**
- The radius of the nucleus is over 10,000 times smaller than the whole atom, but it contains almost **all of the mass** of the atom

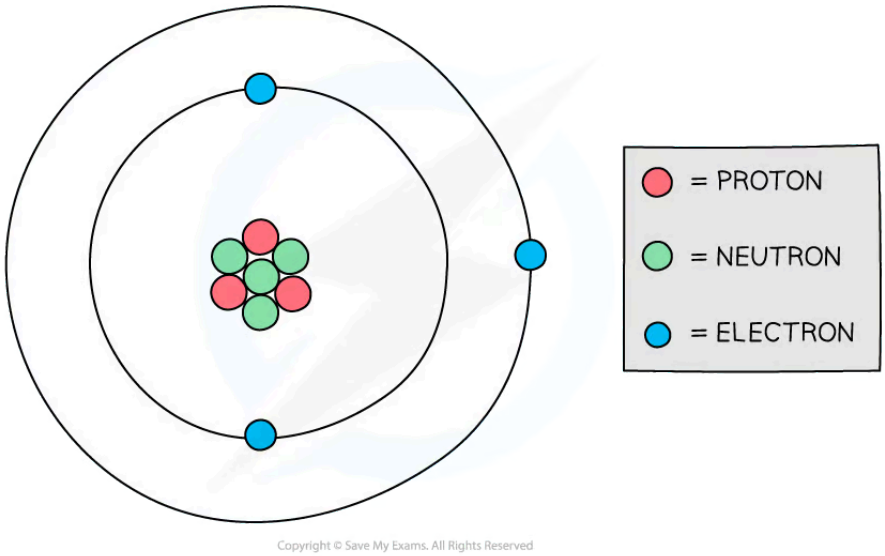

Diagram showing the structure of a Lithium atom. If drawn to scale then the electrons would be around 100 metres away from the nucleus!

Parts of the Atom

- The nucleus contains:
  - **Protons** - positively charged particles with a relative atomic mass of one unit
  - **Neutrons** – no charge, and also with a relative atomic mass of one unit

- Almost all of the atom is empty space, but moving around the nucleus there are:
  - **Electrons** – negative charge with almost no mass (1/2000 the mass of a proton or neutron)
- The properties of each of the particles are shown in the table below:

Particle	Location	Relative Charge	Relative Mass
Proton	In the nucleus	+1	1
Neutron	In the nucleus	0	1
Electron	Orbiting the nucleus	−1	1/2000 (Negligible)

Examiner Tips and Tricks

There are many different models of the atom, such as the **Plum Pudding Model.** But for your exam, make sure to only use the model and descriptions described here!

Your notes

Circuit Diagrams

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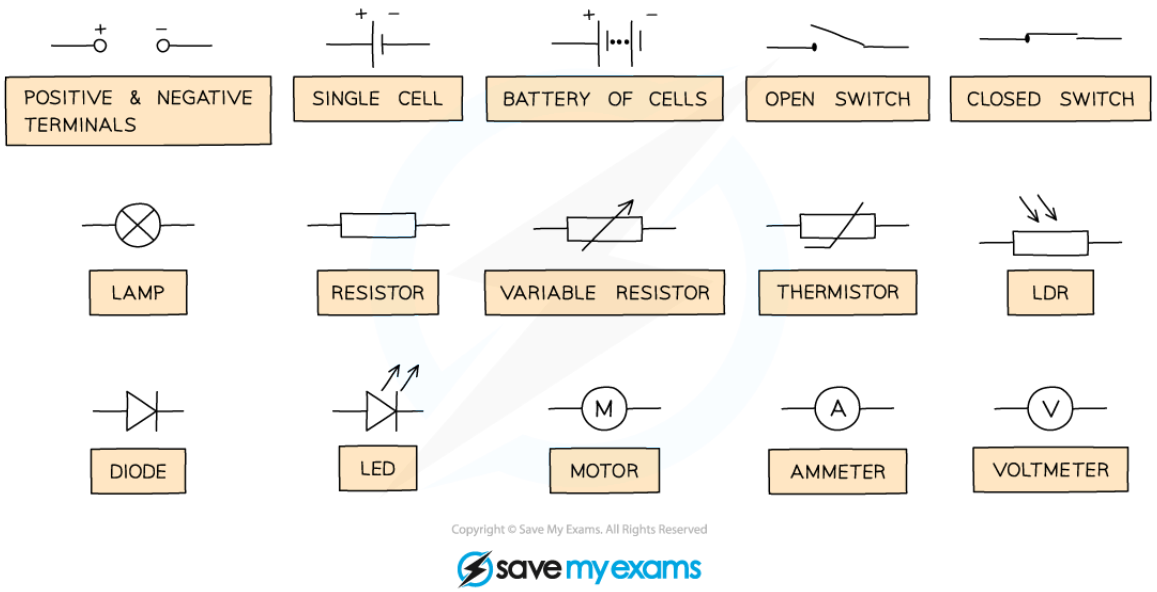
Circuit Diagrams

- All students in the GCSE examination will be expected to recognise the following standard circuit symbols and be able to construct circuits using them:



Common circuit symbols

- The function of the most common components are:
  - **Cell / battery:** Provides the circuit with a source of potential difference - i.e. **energy** per unit of charge. A battery is two or more cells
  - **Switch:** Turn the circuit on (closed), or off (open)
  - **Fixed resistor:** A resistor limits the flow of current. A fixed resistor has a resistance it cannot change
  - **Variable resistor:** A resistor with a slider that can be used to change its resistance. These are often used in dimmer switches and volume controls
  - **Thermistor:** The resistance of a thermistor depends on its temperature. As its temperature increases, its resistance decreases and vice versa
  - **Light-dependent resistor (LDR):** The resistance of an LDR depends on the light intensity. As the light intensity increases, its resistance decreases and vice versa

- **Motor**: A device that converts electrical energy to mechanical energy
- **Diode:** A diode allows current to flow in one direction only. They are used to convert AC to DC current
- **Light-emitting diode (LED):** This is equivalent to a diode and emits light when a current passes through it. These are used for aviation lighting and displays (TVs, road signs)
- **Ammeter:** Used to measure the current in a circuit. Connected in series with other components
- **Voltmeter:** Use to measure the potential difference of an electrical component. Connected in parallel with the relevant component

- Each of these components have an electrical resistance that may impact the current in the circuit
  - However, the resistance of the ammeter and voltmeter are taken as negligible in exam questions


Your notes

Drawing & Interpreting Circuit Diagrams

- Being able to draw and interpret circuit diagrams using circuit symbols is an essential skill in the electricity & circuits topic
- Electric circuit diagrams require the following to work correctly:
  - An **energy source** – This is a source of **potential difference** so a current can flow. This can be a cell, battery, or a power supply
  - A **closed path** or a **complete circuit** – Electrons need to flow in a complete loop for a current to flow. A circuit can be open and closed using a switch
  - **Electrical components** – These could act as sensors that respond to the environment (LDR, thermistor), or measure a value (ammeter, voltmeter), or transfer electrical energy to other forms of energy (LED, lamp). These must be drawn with the correct circuit symbol
- The key rules to remember are:
  - An ammeter is always connected in **series**
  - A voltmeter is always connected in **parallel** to the component the voltage is being measured
  - The direction of current flow is always from the **positive** to the **negative** terminal of the power supply

Worked Example

Which circuit diagram correctly represents a circuit with current flowing through?

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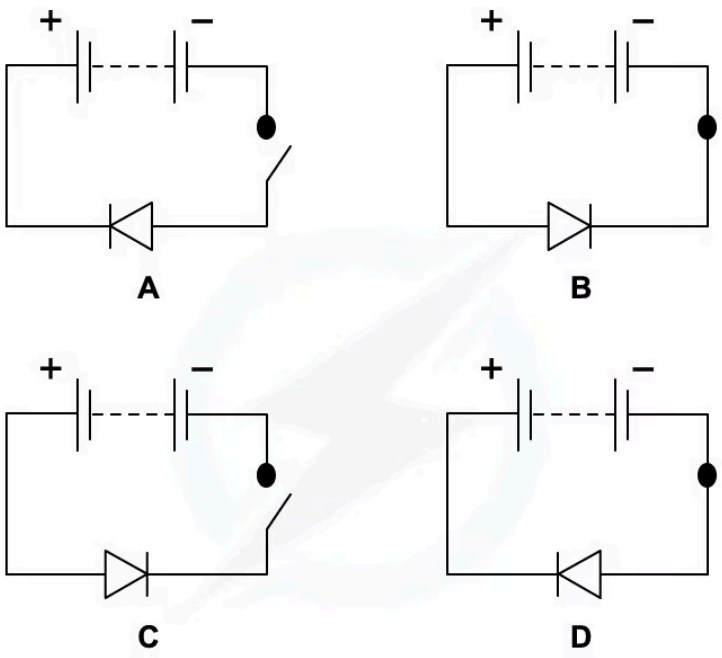
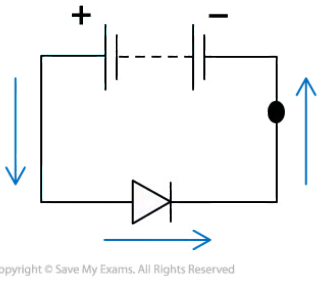


ANSWER: B

THIS IS SEEN IN CIRCUIT B



- For a circuit to be connected, the switch must be closed
  - This is either circuit **B** or **D**
- The other circuit symbol is a diode
  - Diodes only allow current to flow in one direction
- Since current flow is from positive to negative, a forward-biased diode must point in this direction in order for the current to flow
  - This is seen in circuit **B**

Examiner Tips and Tricks

When asked to draw a circuit diagram, make sure to draw the wires as straight lines with a straight edge or a ruler and make it as neat as possible, especially the circuit symbols. If the diagram is too small or there is ambiguity as to what a symbol represents, the examiner may not award you full marks!

Your notes

Potential Difference

Your notes

Potential Difference

- The terminals of a cell make one end of the circuit **positive** and the other **negative**
- This sets up a **potential difference** across the circuit
  - This is sometimes known as the **voltage**
- Potential difference is defined as:

  The amount of energy transferred per unit of charge passing through the terminals
- This means that one **volt** (the unit of potential difference) is equivalent to one **joule** (the unit of energy) per **coulomb** (the unit of charge):

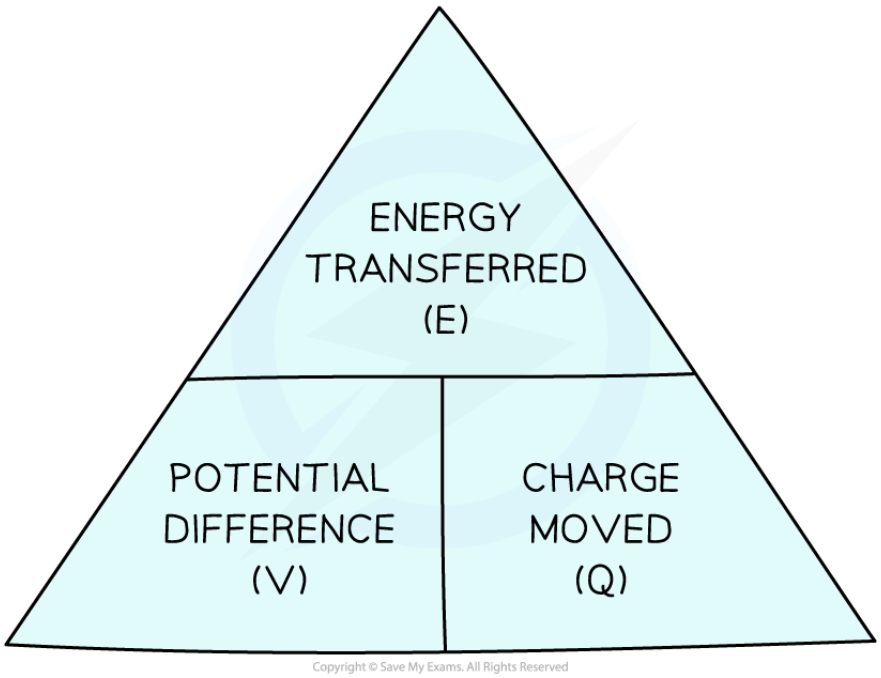
$$1\,V = 1\,J / C$$

- Potential difference can be calculated using the equation below:

$$\text{Potential difference} = \frac{\text{energy transferred}}{\text{charge moved}}$$

$$V = \frac{E}{Q}$$

- Where:
  - V = potential difference, measured in **volts** (V)
  - E = energy transferred, measured in **joules** (J)
  - Q = charge moved, measured in **coulombs** (C)
- The equation for potential difference can be rearranged using the formula triangle below:



Energy, charge, potential difference formula triangle

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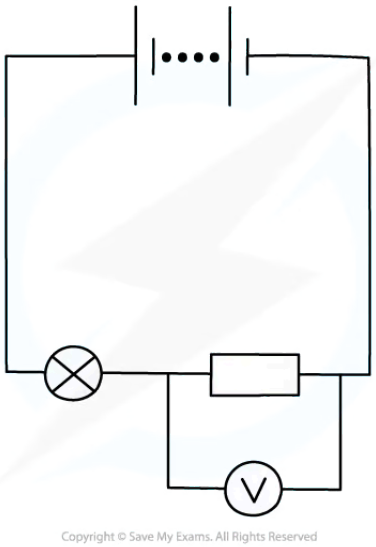
Voltmeters

- Potential difference (or voltage) is measured using a **voltmeter**
- A voltmeter is always set up in **parallel** to the component being measured
  - This is described as measuring voltage '**across**' the component

Your notes



Potential difference (voltage) can be measured by connecting a voltmeter in parallel between two points in a circuit. Here, the voltmeter is measuring the voltage across the resistor

Worked Example

The normal operating voltage (potential difference) for a lamp is 6 V. Calculate how much energy is transferred in the lamp when 4200 C of charge flows through it.

Answer:

Step 1: List the known quantities

- Voltage (potential difference), $V = 6$ V
- Charge moved, $Q = 4200$ C

Step 2: State the equation linking potential difference, energy and charge

- The equation linking potential difference, energy and charge is:

$$V = \frac{E}{Q}$$

Step 3: Rearrange the equation for energy transferred

- Using the formula triangle, the energy transferred is given by:

$$E = V \times Q$$

Step 4: Substitute the known values and calculate the energy transferred

$$E = 6 \times 4200$$

$$E = 25\,200 \text{ J}$$

- Therefore, **25 200 J** of energy is transferred in the lamp

Examiner Tips and Tricks

Don't be confused by the symbol for potential difference (the **symbol** *V*) being the same as its unit (the **volt**, V). Learn the equation and remember especially that one volt is equivalent to 'a joule per coulomb'.

Your notes

Current

Your notes

Current & Charge

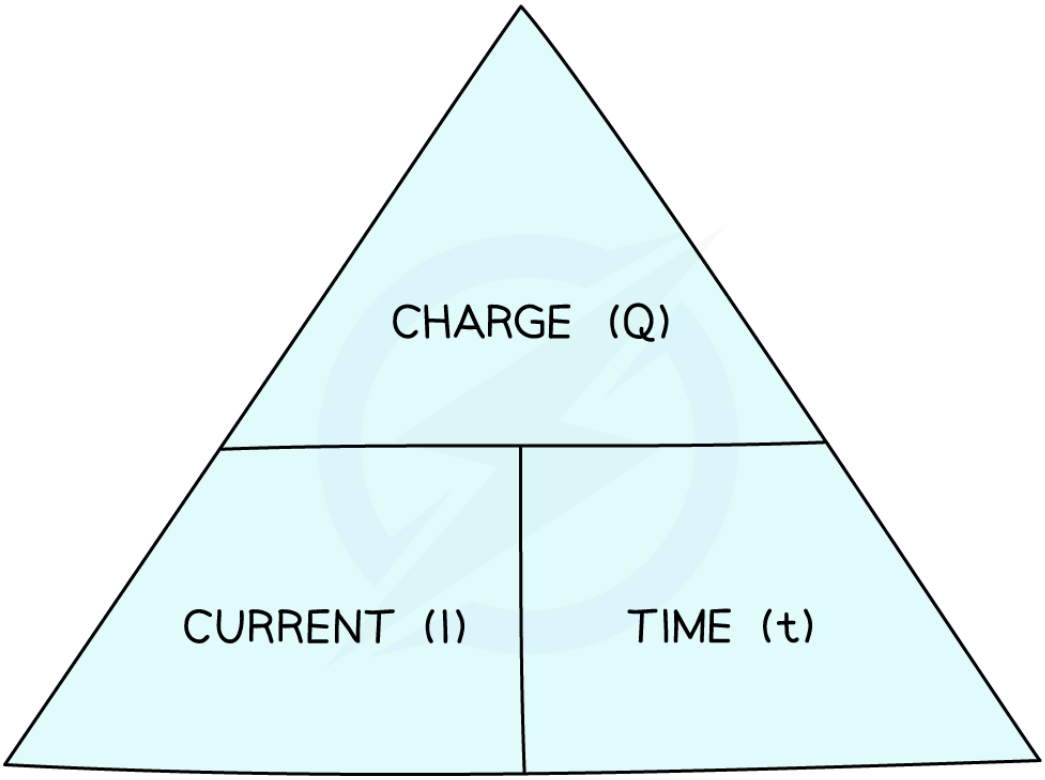
- Electric current is defined as **the rate of flow charge**
  - In other words, the size of an electric current is the amount of charge passing through a component per second
- The current, charge and time are related by the equation:

$$\text{Current} = \frac{\text{charge}}{\text{time}}$$

$$I = \frac{Q}{t}$$

- Where:
  - *I* = current, measured in amperes (or amps, A)
  - Q = charge, measured in coulombs (C)
  - *t* = time, measured in seconds (s)
- The equation for current can be rearranged using the formula triangle below:

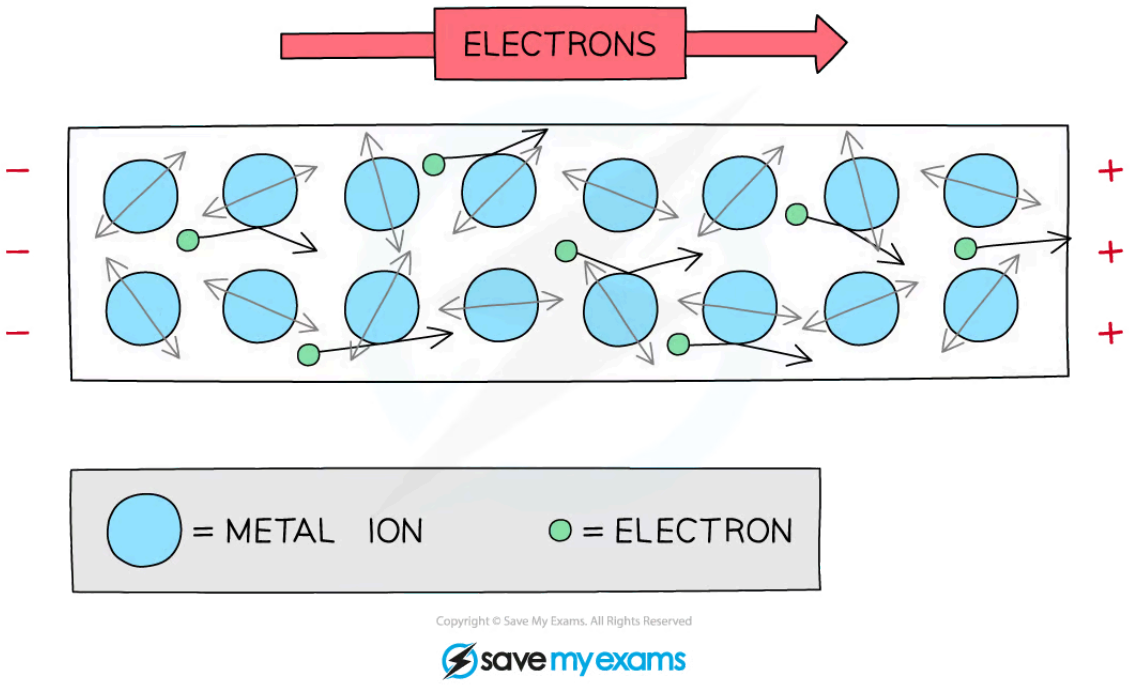
Your notes



Charge, current, time formula triangle

- The wires in an electric circuit are made of **metal**, because metal is a good **conductor** of electric **current**
- In the wires, the current is a flow of **electrons**

Your notes



In metal wires, the current is a flow of electrons. This image shows the electrons flowing through a lattice of metal ions

Worked Example

When will 8 mA of current pass through an electrical circuit?

A. When 1 J of energy is used by 1 C of charge

B. When a charge of 4 C passes in 500 s

C. When a charge of 8 C passes in 100 s

D. When a charge of 1 C passes in 8 s

Answer: B

Step 1: Write out the equation relating current, charge and time

$$I = \frac{Q}{t}$$

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Step 2: Rule out any obviously incorrect options

- Option **A** does not mention time, so can be ruled out

Step 3: Try the rest of the options by applying the equation to determine the correct answer

- Consider option **B**:

$$I = 4 \div 500 = 8 \times 10^{-3} = 8 \text{ mA}$$

- Consider option **C**:

$$I = 8 \div 100 = 80 \times 10^{-3} = 80 \text{ mA}$$

- Consider option **D**:

$$I = 1 \div 8 = 125 \times 10^{-3} = 125 \text{ mA}$$

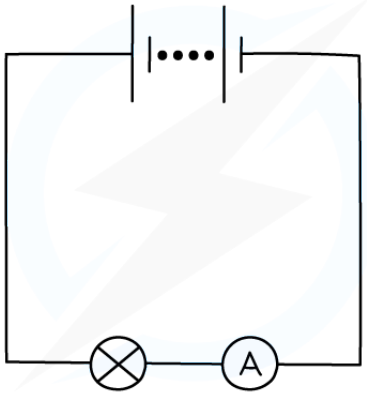
- Therefore, the correct answer is **B**

Examiner Tips and Tricks

Electric currents in everyday circuits tend to be quite small, so it's really common for examiners to throw in a **unit prefix** like 'm' next to quantities of current, e.g. 10 mA (10 milliamperes). Make sure that you are on the lookout for these **prefixes** and that you can convert them into standard units, so 10 mA = 10×10^{-3} A.

Ammeters

- The amount of current flowing through a component is measured using an **ammeter**
- Ammeters should always be connected in **series** with the part of the circuit you wish to measure the current through



Your notes

An ammeter can be used to measure the current around a circuit and always connected in series

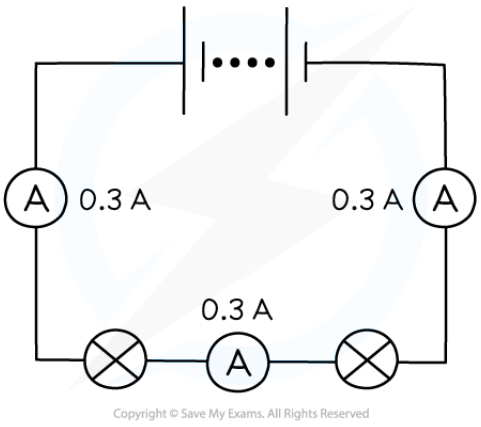
Your notes

Current in Circuits

- A **current** will flow in a circuit if:
  - The circuit includes a source of **potential difference**
  - The circuit is **closed** - i.e. there are no gaps in the circuit
- Sources of potential difference include:
  - A cell
  - Batteries (multiple cells)
  - Electrical generator

Charge Conservation

- In a circuit that is a closed-loop, such as a series circuit, the current is the **same value at any point**
- This is because the number of electrons per second that passes through one part of the circuit is the same number that passes through any other part
- This means that **all** components in a closed-loop have the same current



The current is the same at each point in a closed-loop

Current at a Junction

- At a **junction** in a circuit (where two or more wires meet) the current is **conserved**

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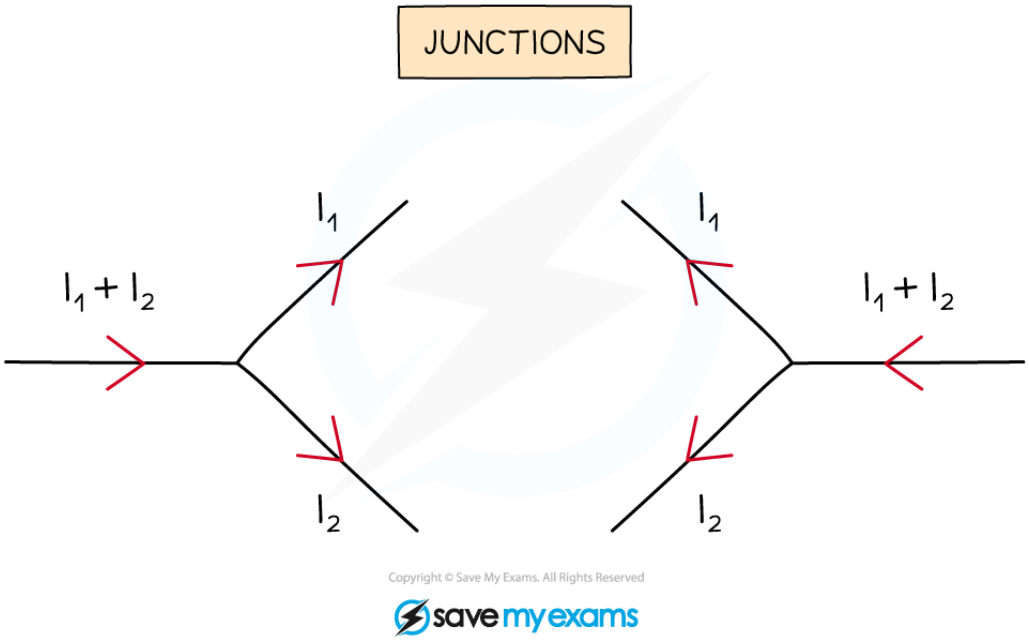
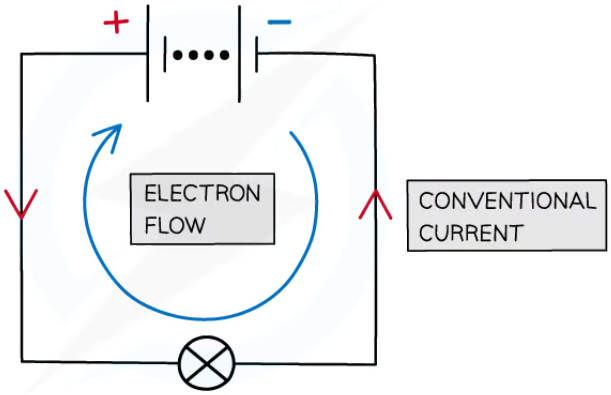
- This means the amount of current flowing into the junction is equal to the amount of current flowing out of it
- This is because **charge** is conserved



The current coming into a junction must equal the current coming out of a junction

- In electrical wires, the current is a flow of **electrons**
- Electrons are negatively charged; they flow away from the negative terminal of a cell towards the positive terminal
- Conventional current is defined as the flow of positive charge from the **positive terminal of a cell to the negative terminal**
  - This is the opposite to the direction of electron flow, as conventional current was described before electric current was really understood

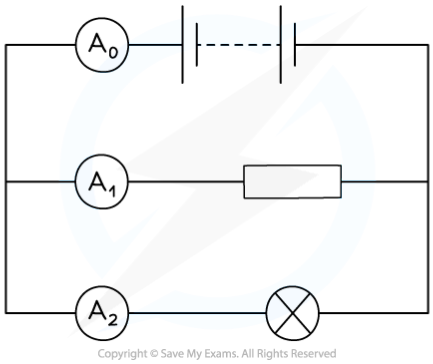
Your notes



By definition, conventional current always goes from positive to negative (even through electrons go the other way)

Worked Example

In the circuit below, ammeter A_0 shows a reading of 10 A, and ammeter A_1 shows a reading of 6 A.



What is the reading on ammeter A_2?

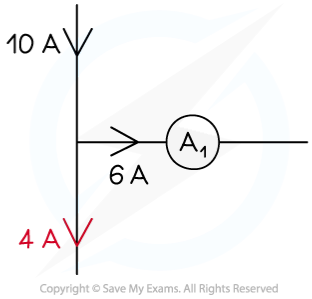
Answer:

Step 1: Recall that at a junction, the current is conserved

- This means that the total amount of current flowing into a junction is equal to the total amount flowing out

Step 2: Consider the first junction in the circuit where current splits

- The diagram below shows the first junction in the circuit



Step 3: Calculate the missing amount of current

- Since 10 A flows into the junction (the total current from the battery), 10 A must flow out of the junction
- The question says that 6 A flows through ammeter A_1 so the remaining current flowing through ammeter A_2 must be:

$$10\ A - 6\ A = \mathbf{4\ A}$$

- Therefore, **4 A** flows through ammeter A_2

Examiner Tips and Tricks

The direction of current flow is super important when considering junctions in a circuit, you should remember that current flows from the **positive** terminal to the **negative** terminal of a cell / battery

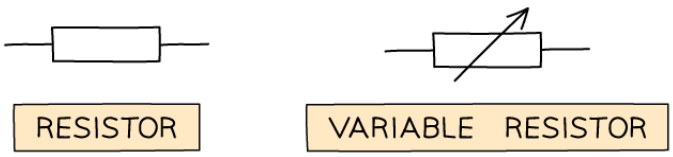
Your notes

Resistance

Your notes

Resistance & Current

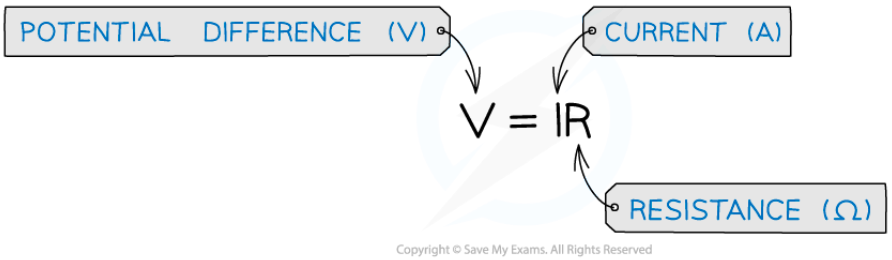
- Resistors come in two types:
  - **Fixed** resistors
  - **Variable** resistors
- Fixed resistors have a resistance that remains **constant**
- Variable resistors can **change** the resistance by changing the **length** of wire that makes up the circuit
  - A **longer** length of wire has **more resistance** than a shorter length of wire
- This therefore can vary the amount of **current** through the circuit:
  - The **larger** the resistance, the **smaller** the current
  - The **smaller** the resistance, the **larger** the current
- For fixed and variable resistors, once the resistance is set, it will stay at this value no matter how the current changes
- However, the resistance of components such as lamps, diodes (diodes and LEDs), thermistors and LDRs (light dependent resistors) **changes** with the current through the component



Fixed and variable resistor circuit symbols

Calculating Resistance

- The current, resistance and potential difference of a component in a circuit are calculated using the equation:



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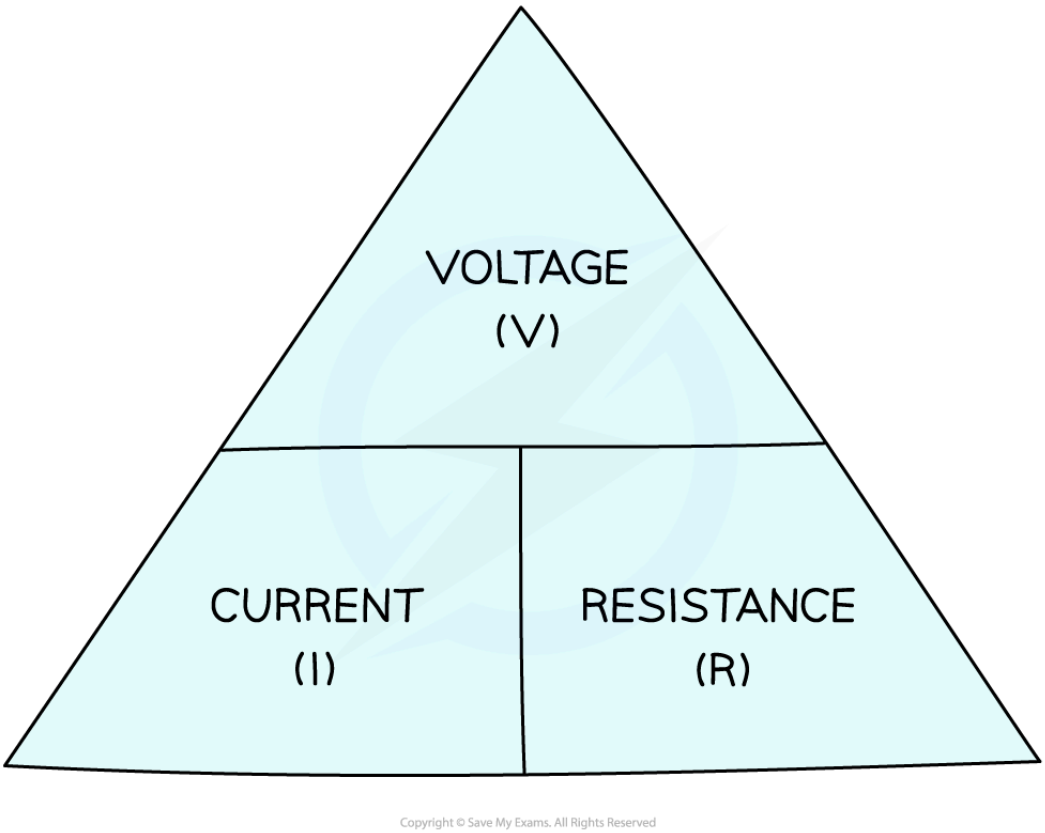
- This equation can be rearranged with the help of the following formula triangle:



Voltage, current, resistance formula triangle

Worked Example

Calculate the potential difference through a resistor of resistance 10 Ω if there is a current of 0.3 A through it.

Answer:

Step 1: List the known quantities

- Resistance, $R = 10\ \Omega$
- Current, $I = 0.3$ A

Step 2: Write the equation relating resistance, potential difference and current

$$V = IR$$

Step 3: Substitute in the values

$$V = 0.3 \times 10 = \mathbf{3\ V}$$

Examiner Tips and Tricks

Remember that 'voltage' and 'potential difference' are the same, either wording will be accepted in your exam answers

Your notes