Current, resistance and potential difference

4.2.1.3 · Electricity · revision notes

How the current through a component depends on the potential difference across it and its resistance, and the equation V = I R. This is one of the most used equations in Paper 1. The required practical on the resistance of a wire and of resistors in series and parallel is also assessed here.

Key facts

- V = I R: pd (V) = current (A) × resistance (Ω)
- Greater resistance → smaller current (for the same pd)
- Resistance of a wire ∝ length (at constant temperature)
- Resistors in series → total resistance up; in parallel → total resistance down
- I = V ÷ R and R = V ÷ I
- 1 kΩ = 1000 Ω; 1 mA = 0.001 A
- Ammeter in series with the wire; voltmeter in parallel across it

Notes

Current, potential difference and resistance

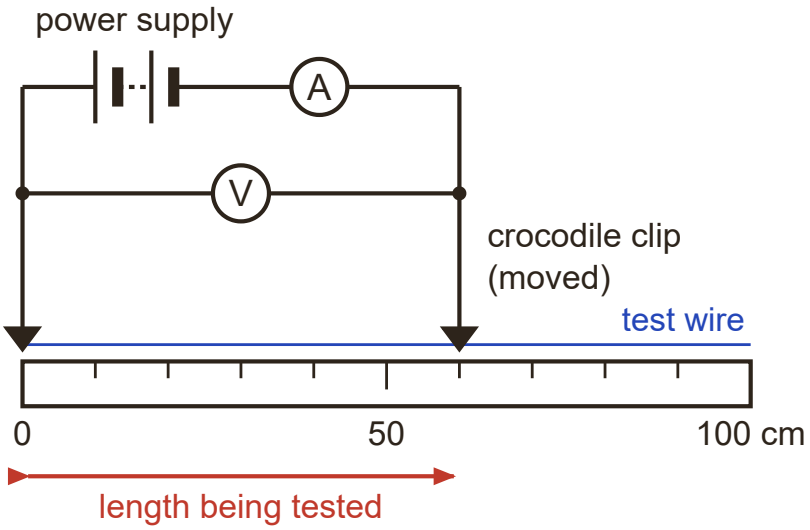
- The current through a component depends on the **potential difference** (pd) across it and on its **resistance**.
- For a given pd, the greater the resistance, the smaller the current.
- For a given resistance, the greater the pd, the greater the current.
- Potential difference is measured in **volts (V)** with a voltmeter. Resistance is measured in **ohms (Ω)**.
- Exam questions use the term 'potential difference' (pd). Using 'voltage' correctly also earns credit.

The equation V = I R

- potential difference = current × resistance: **V = I R** (V in volts, I in amps, R in ohms).
- Rearranged: I = V ÷ R and R = V ÷ I.
- Convert first: kΩ × 1000 = Ω and mA ÷ 1000 = A.

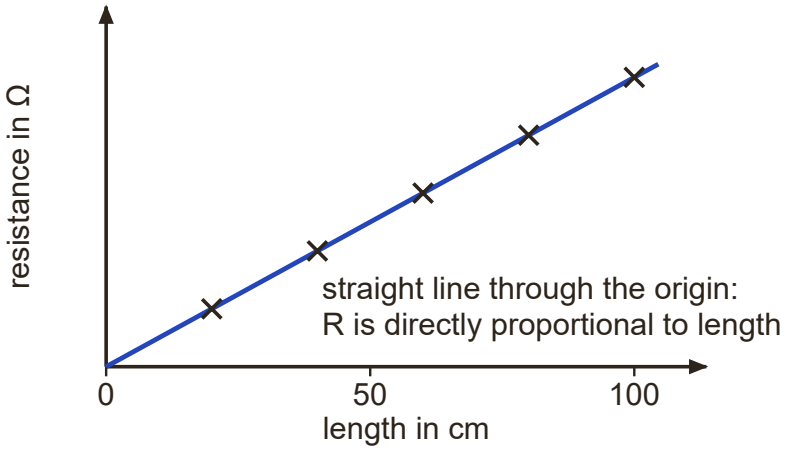
Required practical: resistance of a wire

- Fix a wire along a metre ruler. Connect it in series with an ammeter and a power supply, using crocodile clips, and connect a voltmeter in parallel across the length being tested.



Move one crocodile clip to change the length; R = V ÷ I.

- Measure the current and the pd for a range of lengths (e.g. 10 cm to 100 cm) and calculate R = V ÷ I for each length.
- Keep the same wire (material and thickness) throughout, and keep the temperature constant: use a low current and switch off between readings, because a hotter wire has a higher resistance.
- Hazard: the wire can get hot enough to burn. Keep the current low and do not touch the wire while the current is on.
- For accurate lengths, put the fixed clip exactly at the zero mark. Repeat each reading and calculate a mean resistance.
- Plot resistance (y-axis) against length (x-axis). For a uniform wire you get a straight line through the origin: resistance is **directly proportional** to length.



Resistance against length: straight line through (0, 0).

- The same circuit is used to find the resistance of resistors joined in series and in parallel: measure V and I for each combination and calculate R = V ÷ I.
- Expected result: adding a resistor in series increases the total resistance; adding one in parallel decreases it to less than the smallest resistor.

How to answer each type of question

Calculate using V = I R

2 marks | Grade 4

1. Write V = I R (or the rearranged form you need).
2. Substitute values in V, A and Ω.
3. Give the answer with its unit.

Example. The current through a resistor is 0.30 A. The resistance of the resistor is 40 Ω.
Calculate the potential difference across the resistor.

Model answer.

V = 0.30 × 40 (1)

V = 12 V (1)

Rearrange V = I R, with unit conversions

3 marks | Grade 6

1. Convert kΩ to Ω and mA to A.
2. Rearrange to I = V ÷ R or R = V ÷ I.
3. Calculate, then convert to the unit the question asks for.

Example. A potential difference of 6.0 V is applied across a resistor of resistance 2.4 kΩ.
Calculate the current through the resistor. Give your answer in milliamps.

Model answer.

R = 2.4 × 1000 = 2400 Ω (1)

I = V ÷ R = 6.0 ÷ 2400 = 0.0025 A (1)

I = 2.5 mA (1)

Describe a method: the resistance of a wire

4 to 6 marks | Grade 5

1. Describe the circuit: wire, ammeter and power supply in series; voltmeter across the wire.
2. Say how you measure and change the length (metre ruler, crocodile clips).
3. Say what you record and how you calculate resistance (R = V ÷ I).
4. Give a range of lengths and a control (same wire, low current so the temperature stays constant).

Example. A student investigates how the resistance of a wire depends on its length. She has a power supply, an ammeter, a voltmeter, a metre ruler, two crocodile clips and a long piece of wire. Describe a method she could use. (4 marks)

Model answer. Connect the wire in series with the ammeter and the power supply, with the voltmeter connected in parallel across the length of wire being tested (1). Use the metre ruler to set the length of wire between the crocodile clips, e.g. 20 cm (1). Record the ammeter and voltmeter readings and calculate the resistance using R = V ÷ I (1). Repeat for at least five different lengths, e.g. 20, 40, 60, 80 and 100 cm, keeping the current low and switching off between readings so the temperature of the wire stays constant (1).

Describe a relationship and make a prediction

2 to 3 marks | Grade 7

1. Straight line through the origin: say 'directly proportional'.
2. Straight line not through the origin: say 'as length increases, resistance increases' (a linear relationship).
3. For a prediction, scale up in proportion or read the value from the line.

Example. A graph of resistance against length for a wire is a straight line through the origin. A 50 cm length of the wire has a resistance of 1.6 Ω.
(a) Describe the relationship between resistance and length.
(b) Calculate the resistance of 80 cm of the same wire.

Model answer.

(a) Resistance is directly proportional to length (1)
(b) R = 1.6 × (80 ÷ 50) (1)
R = 2.56 Ω, so about 2.6 Ω (1)

Don’t lose marks

- Multiplying when you should divide: I = V ÷ R, not V × R.
- Forgetting to convert kΩ to Ω or mA to A.
- Saying 'directly proportional' when the line does not go through the origin.
- Letting the wire heat up, which increases its resistance and spoils the results.
- Connecting the voltmeter across the power supply instead of across the wire being tested.

More tips

Memory tricks

- Formula triangle: V on top, I and R underneath.
- Sense check: 12 V across 4 Ω gives 3 A, not 48 A. More resistance should always mean less current.
- Directly proportional = straight line through the origin: double the length, double the resistance.

Exam technique

- Practise using V = I R and rearranging it to find voltage, current or resistance.
- In method questions, name the equipment, say what you measure and how you calculate resistance, give the range of values and say how you keep the test fair.
- Show R = V ÷ I working for each value. The method mark can be awarded even if you slip on the arithmetic.
- If a graph line misses the origin, suggest a systematic error, such as the crocodile clip not being exactly at the zero mark on the ruler.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State the unit of resistance**
Resistance is measured in ohms (Ω).

Grade 4 — **Describe how resistance affects current**
For a given potential difference, the greater the resistance, the smaller the current.

Grade 4 — **Calculate pd using V = I R**
Multiply the current in amps by the resistance in ohms to get the pd in volts.

Grade 5 — **Rearrange V = I R for I or R**
Use I = V ÷ R and R = V ÷ I, converting kΩ and mA first.

Grade 5 — **Describe the resistance of a wire practical**
Measure V and I for different lengths of wire and calculate R = V ÷ I each time.

Grade 7 — **Analyse resistance against length results**
A straight line through the origin shows resistance is directly proportional to length.

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