

ELECTRIC CIRCUITS

LESSON 04 RESISTANCE AND $V = IR$

A dimmer switch makes a lamp glow less brightly. What is it actually changing?

IN THIS LESSON YOU WILL

- describe resistance and its unit, the ohm (Ω)
- use $V = IR$, including mA and $k\Omega$
- recognise an ohmic conductor from data or a graph
- explain why heating a metal increases its resistance

ANSWER EDITION FOR TEACHERS AND SELF-MARKING



NAME

CLASS

TEACHER

TARGET GRADE

HOW THIS BOOKLET WORKS

This is the booklet for **Lesson 4** of the Electric Circuits unit. It builds on the lessons before it; the “Do now” questions and the quick answers at the back help you check what you remember. Keep it: it is your classwork book *and* your revision guide.



DO NOW

Quick questions from earlier lessons. Remembering again is what makes it stick.



LEARN IT

The explanation, diagrams and worked examples. Read this again when you revise.



TRY IT

Practice that builds up: first with support, then on your own.



LAB

Record measurements from a virtual lab or a required practical.



EXAM CORNER

An AQA-style question with a tip on how the marks are given.



REVISE IT

Summary, cover-and-answer questions and an “I can” check to colour in.



Revising at home? (1) Read the Learn it pages. (2) Cover them and answer the “Cover the page” questions in Revise it. (3) Check with the quick answers at the back.

THE ROUTE THROUGH THE UNIT (THIS LESSON IS HIGHLIGHTED)

01 Complete circuits and symbols

03 Potential difference

05 Resistance of a wire RP

07 Resistors in series and parallel RP

09 Investigating I–V characteristics RP

11 Power and energy transfer

02 Current and charge

04 Resistance and $V = IR$

Resistance, $V = IR$, ohmic conductors, why heating raises resistance

06 Series and parallel circuits

08 I–V graphs

10 Thermistors, LDRs and sensors

12 Mains, safety and the National Grid

RESISTANCE AND $V = IR$

AQA Combined 6.2.1.3–6.2.1.4; Physics 4.2.1.3–4.2.1.4; Virtual Lab 3

BIG QUESTION A dimmer switch makes a lamp glow less brightly. What is it actually changing?

BY THE END YOU CAN

- describe resistance and its unit, the ohm (Ω)
- use $V = IR$, including mA and k Ω
- recognise an ohmic conductor from data or a graph
- explain why heating a metal increases its resistance

resistance

ohm (Ω)

ohmic conductor

directly proportional

variable resistor



RETRIEVE

DO NOW

From earlier lessons. No notes!

1

What does '6 V across a lamp' mean?

6 J of energy is
transferred per coulomb.

2

Which meter measures p.d., and how is it connected?

Voltmeter, in parallel
(across).

3

Two lamps are in series with a 6 V battery. One has 2 V across it. What is across the other?

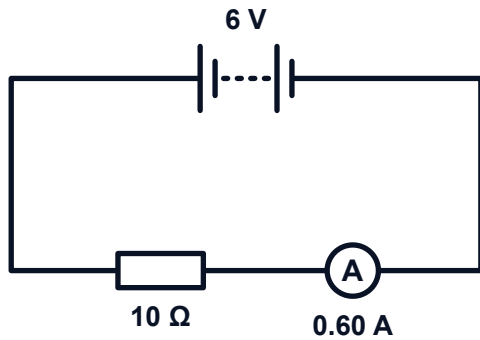
4 V



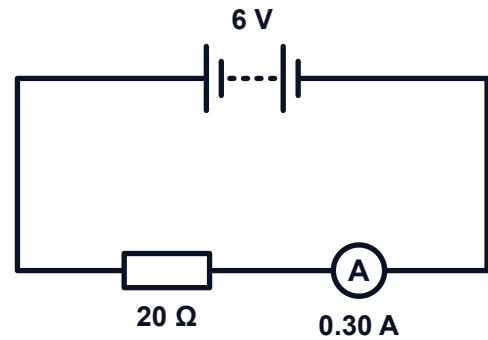
EXPLAIN

CONTROLLING THE CURRENT

Resistance is how much a component **opposes the current**. For the same p.d., a bigger resistance means a smaller current. Resistance is measured in **ohms (Ω)**. A **resistor** has a chosen resistance, such as 10 Ω , to control the current. A **variable resistor** (the dimmer) lets you change it.



Smaller resistance, bigger current.



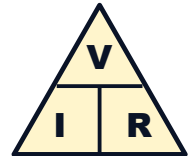
Double the resistance, half the current.

potential difference = current $\times$ resistance

$$V = IR$$

V in volts (V), I in amperes (A), R in ohms (Ω)

Rearranged: $I = V \div R$ and $R = V \div I$



WORKED EXAMPLE

A resistor has 6.0 V across it and a current of 0.30 A through it. Calculate its resistance.

KNOW $V = 6.0 \text{ V}$, $I = 0.30 \text{ A}$

EQUATION $R = V \div I$

SUBSTITUTE $R = 6.0 \div 0.30$

ANSWER $R = 20 \Omega$

YOUR TURN

A lamp has 12 V across it and 0.40 A through it. Calculate its resistance.

KNOW $V = 12 \text{ V}$, $I = 0.40 \text{ A}$

EQUATION $R = V \div I$

SUBSTITUTE $R = 12 \div 0.40$

ANSWER $R = 30 \Omega$

WORKED EXAMPLE

A 150 Ω resistor has 3.0 V across it. Calculate the current in milliamperes (mA).

EQUATION $I = V \div R$

SUBSTITUTE $I = 3.0 \div 150$

ANSWER $I = 0.020 \text{ A}$

CONVERT $0.020 \times 1000 = 20 \text{ mA}$

YOUR TURN

A 500 Ω resistor has 2.0 V across it. Calculate the current in mA.

EQUATION $I = V \div R$

SUBSTITUTE $I = 2.0 \div 500$

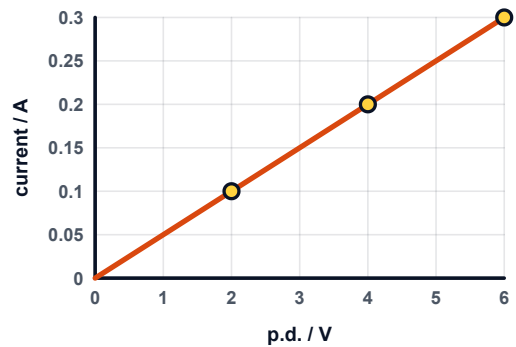
ANSWER $I = 0.0040 \text{ A}$

CONVERT 4.0 mA

OHM'S LAW: OHMIC CONDUCTORS

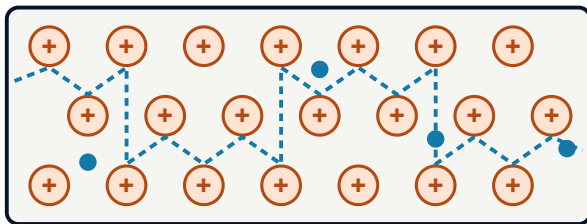
For a **fixed resistor at constant temperature**, the current is **directly proportional** to the p.d.: double the p.d. and the current doubles. The resistance stays the same.

A component like this is an **ohmic conductor**. A graph of current against p.d. is a **straight line through the origin**.



A 20 Ω resistor: straight line through the origin.

WHY IS THERE RESISTANCE?



A free electron collides with the ions as it moves through the wire: this is resistance.

Free electrons keep **colliding with the ions** in the metal. This opposes the flow of charge: resistance.

When the metal gets **hotter**, the ions vibrate more, so there are more collisions and the **resistance increases**. That is why Ohm's law needs 'at constant temperature'.



PRACTISE TRY IT

- 1 Two circuits have the same 6 V battery. Circuit A has a 10 Ω resistor; circuit B has a 30 Ω resistor. Tick **one** box.

- ☒ Circuit A has the bigger current.
 ☐ Circuit B has the bigger current.
 ☐ Both have the same current.
 ☐ You cannot tell.

- 2 **SUPPORTED** Calculate the resistance of a component with 12 V across it and 0.60 A through it.

EQUATION	$R = V \div I$	
SUBSTITUTE	$R = 12 \div 0.60$	
ANSWER	20 Ω	unit:

- 3 **SUPPORTED** A current of 0.20 A flows through a 15 Ω resistor. Calculate the p.d. across it.

EQUATION	$V = I R$	
SUBSTITUTE	$V = 0.20 \times 15$	
ANSWER	3.0 V	unit:

4

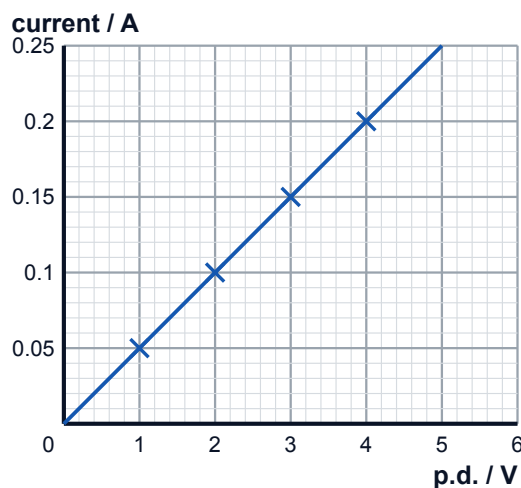
ON YOUR OWN A $220\ \Omega$ resistor has $5.5\ \text{V}$ across it. Calculate the current in mA.

$$I = V \div R = 5.5 \div 220 = 0.025\ \text{A} = 25\ \text{mA}$$

5

A student measures a component. Complete the table, plot the points and draw a line of best fit.

p.d. / V	current / A	$V \div I / \Omega$
1.0	0.05	20
2.0	0.10	20
3.0	0.15	20
4.0	0.20	20



Is the component an ohmic conductor? Use the table and the graph.

Yes: $V \div I$ is constant ($20\ \Omega$) and the graph is a straight line through the origin, so current is directly proportional to p.d.

6

Explain why a resistor only has a constant resistance if its temperature stays the same.

If the resistor gets hotter, the ions ...

If it heats up, the ions vibrate more, so the electrons collide with them more often and the resistance increases. So R is only constant at constant temperature.

**VIRTUAL LAB 3: DISCOVER THE RESISTANCE RULE**

Set the resistor to **10 Ω** . Change only the battery setting. Measure the p.d. across the resistor and the current.

- 7 Record and calculate.

Battery setting / V	p.d. / V	current / A	$V \div I / \Omega$
2	2.0	0.20	10
4	4.0	0.40	10
6	6.0	0.60	10
8	8.0	0.80	10
10	10	1.0	10
12	12	1.2	10

- 8 What happens to the current when the p.d. doubles? What stays constant?

The current doubles (current $\propto$ p.d.). $V \div I$ stays constant at 10 Ω , the resistance.



Get the marks: In part (b) use your answer to (a). Quick check: $3 \times$ the p.d. should give $3 \times$ the current if R is constant.

- 9 A fixed resistor has a p.d. of 2.0 V across it and a current of 0.10 A [2 marks]
through it. Calculate its resistance.

EQUATION	$R = V \div I$	
SUBSTITUTE	$R = 2.0 \div 0.10$	
ANSWER	20 Ω	unit:

- 10 The p.d. is increased to 6.0 V. The temperature stays constant. Calculate [2 marks]
the new current.

$$I = V \div R (1) = 6.0 \div 20 = 0.30 \text{ A (1)}$$

**SUMMARY**

- Resistance opposes the current. Unit: **ohm (Ω)**.
- $V = IR$. Convert mA $\rightarrow$ A ($\div 1000$) and k $\Omega \rightarrow \Omega$ ($\times 1000$).
- Ohmic conductor: $I \propto V$ at constant temperature; the graph is a straight line through the origin.
- Hotter metal $\rightarrow$ ions vibrate more $\rightarrow$ more collisions $\rightarrow$ higher resistance.

COVER THE PAGE AND ANSWER

1 What is the unit of resistance?

3 What does an ohmic conductor's I-V graph look like?

2 Write the equation linking p.d., current and resistance.

4 What happens to a metal's resistance as it heats up?

I CAN...

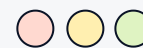
describe resistance and state its unit



use $V = IR$ and its rearrangements



convert mA and k Ω



decide from data or a graph whether a component is ohmic



explain why heating increases resistance



EQUATION TOOLKIT

The equations you have met so far. You will meet these one at a time. Learn each equation **in words** as well as symbols: AQA gives you an equation sheet in the exam (it does not include $R_{\text{total}} = R_1 + R_2$), but knowing the equations by heart makes every question faster.

$$Q = I t$$

Lesson 2

charge flow = current × time

C, A, s

Rearranged: $I = Q \div t$ and $t = Q \div I$

$$E = Q V$$

Lesson 3

energy transferred = charge ×
p.d.

J, C, V

Rearranged: $V = E \div Q$ and $Q = E \div V$

$$V = I R$$

Lesson 4

p.d. = current × resistance

V, A, Ω

Rearranged: $I = V \div R$ and $R = V \div I$

FOUR STEPS FOR EVERY CALCULATION

1

Write down what you know, with units.
Convert units first
(minutes → seconds,
kW → W, mA → A).

2

Write the equation you will use, in symbols.

3

Substitute the numbers, then rearrange if needed.

4

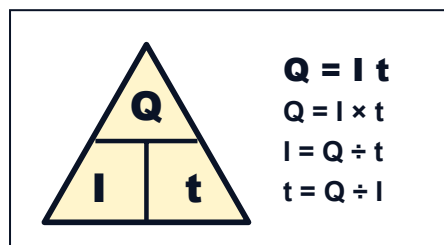
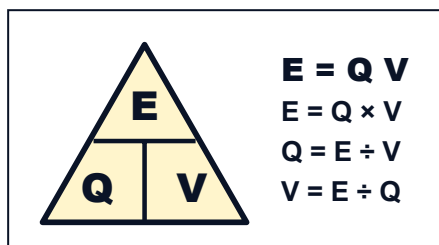
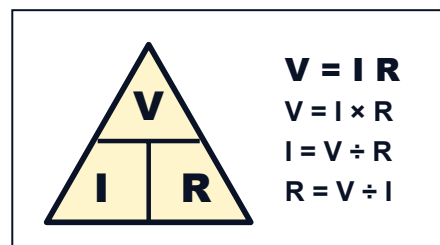
Give the answer with a unit. Ask: is it sensible?

CONVERT	HOW	EXAMPLE
minutes → seconds	× 60	3.0 min = 180 s
hours → seconds	× 3600	2.0 h = 7200 s
milliamps (mA) → amps (A)	÷ 1000	250 mA = 0.25 A
kilowatts (kW) → watts (W); kilohms (k Ω) → ohms (Ω)	× 1000	2.2 kW = 2200 W
kilovolts (kV) → volts (V)	× 1000	400 kV = 400 000 V

EQUATION TRIANGLES: HELP WITH REARRANGING

- 1 Cover the quantity you want to find.
- 2 The two left **side by side**? **Multiply** them.
- 3 One **above** the other? **Divide** the top by the bottom.

Example: to find I from $Q = I t$, cover I . Q is above t , so $I = Q \div t$. Triangles only help with rearranging: you still need to learn each equation.



REFERENCE

KEY WORDS FROM THIS LESSON

Learn the meaning and spelling. In exams, precise words earn marks: say “p.d. across” and “current through”.

Directly proportional: If one quantity doubles, the other doubles. The graph is a straight line through the origin.

Ohm (Ω): Unit of resistance.

Ohmic conductor: Current is directly proportional to p.d. at constant temperature.

Resistance (R): How much a component opposes the current. Unit: ohm (Ω).

CHECK YOURSELF

QUICK ANSWERS

Answers to the “Do now” and “Cover the page” questions, so you can check yourself when revising. Answers to the longer questions are in your teacher's answer edition.

DO NOW

1. 6 J of energy is transferred per coulomb.
2. Voltmeter, in parallel (across).
3. 4 V

COVER THE PAGE

1. Ohm (Ω)
2. $V = I R$
3. A straight line through the origin.
4. It increases.