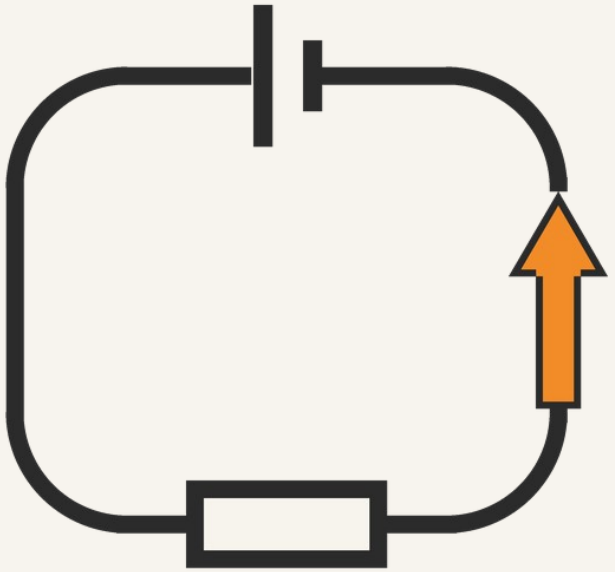
BOOKLET 3 · ELECTRONICS AND ANALOGUE CONTROL

Ohm's Law and Resistors



One relationship, and the two rules that go with it.

National 5 Engineering Science

Daily Review

Lesson 1 — Circuits and Circuit Symbols

1. State the rule for current in a series circuit.

2. Where does an ammeter go in a circuit?

3. Draw the symbol for an LDR.

4. What is the unit of resistance?

5. What does a diode do?

PART 1

Ohm's Law

Voltage, current and resistance are not three separate ideas — they are one relationship.

By the end of this part…

1. I can apply Ohm's Law to circuit calculations
2. I can rearrange a formula to find an unknown quantity

What Ohm's Law says

Booklet p.9

The idea

More voltage, more current. More resistance, less current.

The relationship

Voltage equals current times resistance.

Why it matters

On your data sheet, and used in nearly every circuit question.

Ohm's Law

Booklet p.9 — on the data sheet

$$V = I \ R$$

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

Three ways to write it

Booklet p.9

Finding voltage

$$V = I \ R$$

you know I and R

Finding current

$$I = V/R$$

you know V and R

Finding resistance

$$R = V/I$$

you know V and I

Cover the one you are looking for. What is left is the sum.

Worked example — find the resistance · p.9

A buzzer has 9 V across it and a current of 0.15 A through it.

Calculate the resistance of the buzzer.

V = 9 V

I = 0.15 A

R = ?

$V = I \ R$

$R = V/I$

$R = 9/0.15$

$\underline{R = 60\ \Omega}$

Worked example — find the current · p.9

A 240 Ω resistor is connected across a 12 V supply.

Calculate the current in the resistor.

$V = 12\ V$

$R = 240\ \Omega$

$I = ?$

$V = I\ R$

$I = V/R$

$I = 12/240$

$\underline{I = 0.05\ A}$

Show me — which form do I need?

SHOW ME BOARDS

1. You know the voltage and the current. What are you finding?
2. You know the current and the resistance. Which form do you use?
3. You know the voltage and the resistance. Which form do you use?
4. A question gives 6 V and 300 Ω and asks for the current. Which form?
5. A question gives 2 A and 5 Ω and asks for the voltage. Which form?

Show me — which form do I need?

SHOW ME BOARDS

EXTRA PRACTICE

1. You are asked for resistance. What two things must you be given?
2. You are asked for voltage. What two things must you be given?
3. A question gives 12 V and 0.5 A and asks for resistance. Which form?
4. A question gives 9 V and 45 Ω and asks for current. Which form?
5. A question gives 0.2 A and 50 Ω and asks for voltage. Which form?

Show me — Ohm's Law

SHOW ME BOARDS

1. 0.5 A flows through 20 Ω. Find the voltage.
2. 10 V across 5 Ω. Find the current.
3. 6 V across a resistor gives 0.3 A. Find the resistance.
4. 2 A through 12 Ω. Find the voltage.
5. 24 V across 8 Ω. Find the current.

Show me — Ohm's Law

SHOW ME BOARDS

EXTRA PRACTICE

1. 0.4 A flows through 25 Ω. Find the voltage.
2. 18 V across 9 Ω. Find the current.
3. 12 V across a resistor gives 0.4 A. Find the resistance.
4. 1.5 A through 4 Ω. Find the voltage.
5. 30 V across 6 Ω. Find the current.

Your turn — TRY THIS

Booklet p.9 — TRY THIS: Ohm's Law

Answer the three questions in your booklet.
3 marks each: relationship, substitution,
then the answer with its unit.

Booklet p.9 — TRY THIS: Ohm's Law

TRY THIS — Answers

ANSWERS

Booklet p.9 — Ohm's Law

Q	Working	Answer
1	$R = 12 \div 0.5$	24 Ω
2	$I = 5 \div 220$	0.0227 A (22.7 mA)
3	$R = 24 \div 2$	12 Ω

3 marks each: relationship · substitution · answer with unit.

Watch out

THE MISTAKE

- Substituting 4.7 kΩ as 4.7
- Substituting 50 mA as 50
- Writing the answer with no unit

THE CORRECT ANSWER

- 4.7 kΩ is 4700 Ω
- 50 mA is 0.05 A
- V, A or Ω — every time

Checkpoint

1. State Ohm's Law and give the unit of each quantity.

2. A 100 Ω resistor carries 0.1 A. Find the voltage across it.

3. Two circuits have the same supply voltage, but one has more resistance. Which carries the larger current, and why?

Daily Review

Part 1 — Ohm's Law

1. State Ohm's Law.

2. Which form finds the current?

3. 12 V across 6 Ω. Find the current.

4. How many ohms is 2.2 kΩ?

5. What is the unit of current?

PART 2

Resistors in Series

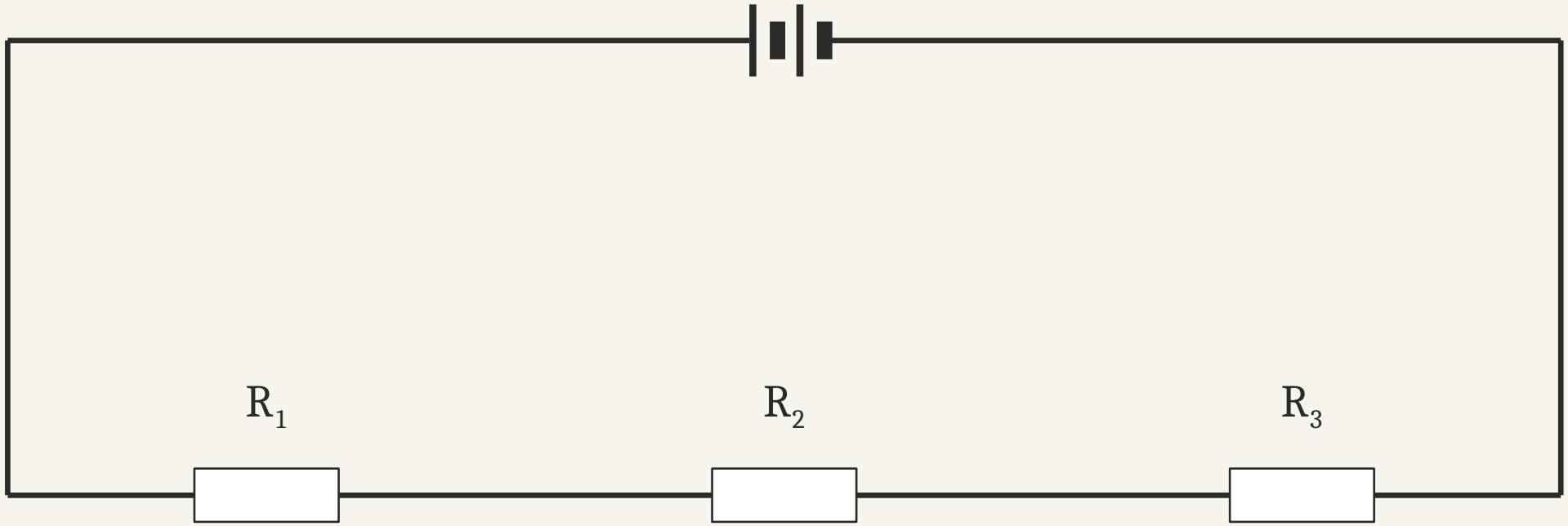
One path, so every resistance the current meets is added on.

By the end of this part…

1. I can calculate total resistance for resistors in series

Series — the resistances add

Booklet p.10



One path, so the current meets every resistance in turn.

Total resistance in series

Booklet p.10 — on the data sheet

$$R_T = R_1 + R_2 + R_3 + \ldots$$

R_T	R_1, R_2, R_3
total resistance, in ohms (Ω)	each resistance, in ohms (Ω)

Worked example — three in series · p.10

A 47 Ω, a 68 Ω and a 150 Ω resistor are connected in series.

Calculate the total resistance.

$R_1 = 47\ \Omega$

$R_2 = 68\ \Omega$

$R_3 = 150\ \Omega$

$R_T = ?$

$$R_T = R_1 + R_2 + R_3$$

$$R_T = 47 + 68 + 150$$

$$\underline{R_T = 265\ \Omega}$$

Watch out — the total is bigger

Booklet p.10

The check

A series total is always LARGER than the largest single resistor. 265 Ω is bigger than 150 Ω.

What it does

More resistance on one path means less current for the same supply voltage.

Show me — series totals

SHOW ME BOARDS

1. 10 Ω and 20 Ω in series.
2. 100 Ω, 200 Ω and 300 Ω in series.
3. Three 50 Ω resistors in series.
4. 1 kΩ and 3 kΩ in series. Give the answer in ohms.
5. A 12 Ω and a 6 Ω resistor in series carry 0.5 A. Find the supply voltage.

Show me — series totals

SHOW ME BOARDS

EXTRA PRACTICE

1. 40 Ω and 60 Ω in series.

2. 220 Ω, 330 Ω and 450 Ω in series.

3. Four 25 Ω resistors in series.

4. 2 kΩ and 5 kΩ in series. Give the answer in ohms.

5. A 15 Ω and a 5 Ω resistor in series carry 0.4 A. Find the supply voltage.

Your turn — TRY THIS

Booklet p.10 — TRY THIS: Series Resistance

Answer the three questions in your booklet.
Watch question 2 — the resistances are in kΩ.
Convert them to ohms before you add.

Booklet p.10 — TRY THIS: Series Resistance

TRY THIS — Answers

ANSWERS

Booklet p.10 — Series Resistance

Q	Working	Answer
1	$R_T = 220 + 330$	550 Ω
2	$R_T = 1000 + 2000 + 4700$	7700 Ω (7.7 kΩ)
3	$R_T = 4 \times 100$	400 Ω

Every total is bigger than the biggest resistor in it.

Daily Review

Part 2 — Resistors in Series

1. State the rule for total resistance in series.

2. 47 Ω and 53 Ω in series. Find the total.

3. State Ohm's Law.

4. Is a series total bigger or smaller than the biggest resistor?

5. How many ohms is 4.7 kΩ?

PART 3

Resistors in Parallel

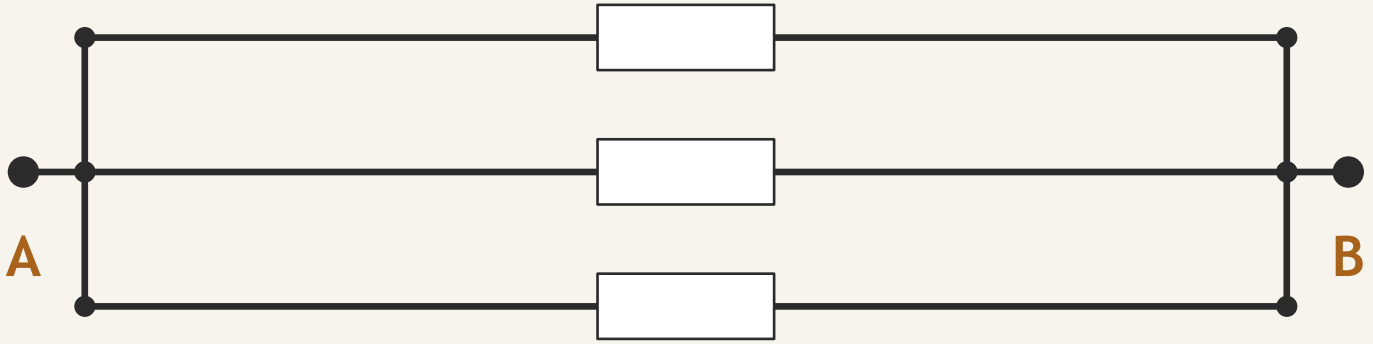
Give the current a second path and the total resistance falls.

By the end of this part…

1. I can calculate total resistance for resistors in parallel
2. I can compare calculated, simulated and measured values

Parallel — a second path

Booklet p.11



Each branch is another way through, so less opposes the current.

Total resistance in parallel

Booklet p.11 — on the data sheet

$$1/R_T = 1/R_1 + 1/R_2 + \ldots$$

R_T

total resistance, in ohms (Ω)

R_1, R_2

each branch resistance, in ohms (Ω)

The two-resistor shortcut

Booklet p.11

$$R_T = (R_1 \times R_2)/(R_1 + R_2)$$

Use it

for exactly TWO resistors in parallel

Not for three

three branches need the reciprocal form

Worked example — two in parallel · p.11

A 60 Ω lamp and a 40 Ω lamp are connected in parallel.

Calculate the total resistance.

$R_1 = 60\ \Omega$

$R_2 = 40\ \Omega$

$R_T = ?$

$$R_T = (R_1 \times R_2)/(R_1 + R_2)$$

$$R_T = (60 \times 40)/(60 + 40)$$

$$R_T = 2400/100$$

$$\underline{R_T = 24\ \Omega}$$

Worked example — three in parallel · p.11

A 2 kΩ, a 3 kΩ and a 6 kΩ resistor are connected in parallel.

Calculate the total resistance.

$R_1 = 2000\ \Omega$

$R_2 = 3000\ \Omega$

$R_3 = 6000\ \Omega$

$R_T = ?$

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3$$

$$1/R_T = 1/2000 + 1/3000 + 1/6000$$

$$1/R_T = 1/1000$$

$$\underline{R_T = 1000\ \Omega}$$

Watch out

THE MISTAKE

- Stopping when you have found $1 \div R_T$
- A total bigger than the smallest branch
- Using the shortcut on three resistors

THE CORRECT ANSWER

- Turn it upside down to get R_T
- A parallel total is ALWAYS smaller
- The shortcut is for two branches only

Show me — parallel totals

SHOW ME BOARDS

1. Two 100 Ω resistors in parallel.
2. 20 Ω and 30 Ω in parallel.
3. Three 60 Ω resistors in parallel.
4. Is 12 Ω a possible total for 20 Ω and 30 Ω in parallel?
5. A parallel pair has a total of 40 Ω. Can either branch be 30 Ω?

Show me — parallel totals

SHOW ME BOARDS

EXTRA PRACTICE

1. Two 50 Ω resistors in parallel.
2. 12 Ω and 24 Ω in parallel.
3. Three 30 Ω resistors in parallel.
4. Is 25 Ω a possible total for 40 Ω and 60 Ω in parallel?
5. A parallel pair has a total of 15 Ω. Can either branch be 10 Ω?

Your turn — TRY THIS

Booklet p.11 — TRY THIS: Parallel Resistance

Answer the three questions in your booklet.
Two branches — use the shortcut.
Three branches — use the reciprocal form,
then remember to invert at the end.

Booklet p.11 — TRY THIS: Parallel

TRY THIS — Answers

ANSWERS

Booklet p.11 — Parallel Resistance

Q	Working	Answer
1	$R_T = (470 \times 470) \div 940$	235 Ω
2	$R_T = (100 \times 1000) \div 1100$	90.9 Ω
3	$1 \div R_T = 0.01 + 0.005 + 0.0025$	57.1 Ω

Every total is smaller than the smallest branch.

Simulate it — check both networks

Yenka · success criterion 2.6

Build the 47 Ω, 68 Ω and 150 Ω series chain.
PREDICT the ohmmeter reading first.
Then build 60 Ω and 40 Ω in parallel.
Predict again, then run it and record both.

Yenka — series and parallel networks

What the simulation shows

ANSWERS

Yenka · success criterion 2.6

Network	Calculated	What Yenka shows
47 + 68 + 150 in series	265 Ω	265 Ω
60 and 40 in parallel	24 Ω	24 Ω

A simulation has no tolerance. Real resistors are ±5 %, so a measured value sits near the calculation, not on it.

Exam practice

National 5 Engineering Science 2024 Q8 — a child's microphone

Part	What it asks	Marks
8(a)(i)	the resistance of the parallel branch	2
8(a)(ii)	the total resistance, with R set to 780 Ω	2
8(b)	the ammeter reading when V_1 is 1.2 V	3

Find the relationship on your data sheet first — every time.

LOOKING AHEAD

Electrical Power

Three relationships, and how to pick the right one.

Plenary

1. State Ohm's Law and rearrange it to find the current.
2. Three resistors in series: 12 Ω, 18 Ω and 20 Ω. Find the total.
3. Two 200 Ω resistors in parallel. Find the total.
4. Why is a parallel total always smaller than the smallest branch?
5. A calculation gives 265 Ω but the meter reads 258 Ω. Why?

Plenary

EXTRA PRACTICE

1. State Ohm's Law and rearrange it to find the resistance.
2. Three resistors in series: 33 Ω, 47 Ω and 20 Ω. Find the total.
3. Two 90 Ω resistors in parallel. Find the total.
4. Why does adding a resistor in series reduce the current?
5. Give one reason a simulated value and a measured value differ.

Extension

1. Four 100 Ω resistors. What is the largest total resistance you can make, and the smallest?

2. A 10 Ω resistor is put in parallel with a 1 MΩ resistor. Estimate the total without a calculator, and say why.

3. A 6 V supply drives 0.02 A through a series pair. One resistor is 100 Ω. Find the other.

Extension

EXTRA PRACTICE

1. Three 60 Ω resistors. List every total resistance you can make with all three.

2. A 5 Ω resistor is put in series with a 5 MΩ resistor. Estimate the total without a calculator, and say why.

3. A 12 V supply drives 0.04 A through a series pair. One resistor is 200 Ω. Find the other.