E2.4 Parallel circuits and Kirchhoff's 1st law

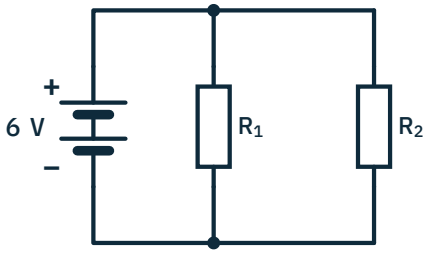
LEARNING INTENTION

We are learning how current, voltage and resistance behave in parallel circuits.

SUCCESS CRITERIA – I CAN

- ☐ state that each branch has the same voltage
- ☐ use Kirchhoff's 1st law to find a branch current
- ☐ calculate total resistance in parallel
- ☐ explain why parallel resistance is less than the smallest branch

Parallel rules



Two resistors in parallel

Components in **parallel** are on separate branches between the same two points.

Voltage is the same across each branch.

Current splits: the total current equals the sum of the branch currents. This is **Kirchhoff's 1st law**.

Resistance: adding a branch gives the current another path, so R_t goes **down**.

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$1/R_t = 1/R_1 + 1/R_2 + \ldots$
resistors in parallel

$R_t = R_1 \times R_2/(R_1 + R_2)$
two resistors in parallel

$I_t = I_1 + I_2 + \ldots$
Kirchhoff's 1st law

$V = IR$
Ohm's law

WORKED EXAMPLE Two resistors in parallel

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
$V_s = 6.0$ V $R_1 = 3.0$ kΩ $R_2 = 6.0$ kΩ	R_t and I_t	$R_t = R_1 \times R_2/(R_1 + R_2)$ $I = V/R$	$R_t = (3 \times 6) \div (3 + 6) = 2.0$ kΩ $I_t = 6.0 \div 2.0$	**$I_t = 3.0$ mA** $R_t = 2.0$ kΩ

Kirchhoff 1 check: $I_1 = 6 \div 3 = 2$ mA, $I_2 = 6 \div 6 = 1$ mA; $2 + 1 = 3$ mA ✓

WORKED EXAMPLE Three in parallel

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
$R_1 = 10$ kΩ $R_2 = 10$ kΩ $R_3 = 5$ kΩ	R_t	$1/R_t = 1/R_1 + 1/R_2 + 1/R_3$	$1/R_t = 0.1 + 0.1 + 0.2 = 0.4$ $R_t = 1 \div 0.4$	**$R_t = 2.5$ kΩ**

Don't forget the last step: turn $1/R_t$ back into R_t.

Parallel circuits and Kirchhoff's 1st law

SHORT CIRCUIT

× WHAT EXAMINERS SAW

Pupils stopped at $1/R_t = 0.4$ and gave $R_t = 0.4$ kΩ, or added parallel resistors like series ones.

✓ THE FIX

Always finish with $R_t = 1 \div$ (your sum). Sense check: R_t in parallel is **less than the smallest** branch resistance.

Common error in parallel resistance questions.

V same

Every branch has the full supply voltage.

I splits

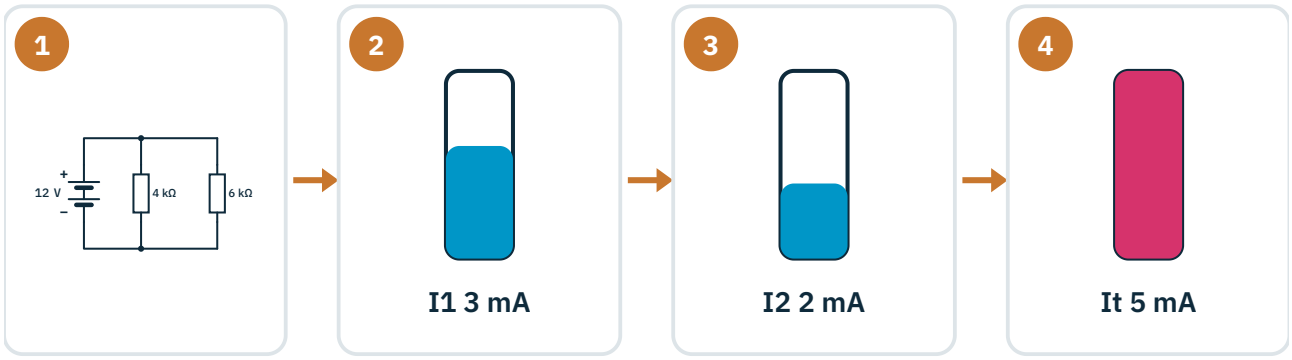
$I_t = I_1 + I_2 + \ldots$ (Kirchhoff 1)

R_t falls

R_t is less than the smallest branch.

Splitting the current

KIRCHHOFF'S 1ST LAW IN FOUR STEPS



Same 12 V across each branch

Smaller R: bigger current

Bigger R: smaller current

Currents add at the junction

WORKED EXAMPLE **Branch currents**

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
$V_s = 12$ V $R_1 = 4$ kΩ, $R_2 = 6$ kΩ	I_1, I_2, I_t	$I = V/R$ (same V on each branch) $I_t = I_1 + I_2$	$I_1 = 12/4000 = 3$ mA $I_2 = 12/6000 = 2$ mA	$I_t = 5$ mA

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WORKED EXAMPLE **Product over sum**

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
R_1 = 220 Ω, R_2 = 330 Ω	R_t	$R_t = R_1 \times R_2 / (R_1 + R_2)$	= 220 × 330 / 550	**132 Ω**

R_t is always smaller than the smallest branch.

WRONG

R_t = 220 + 330 = 550 Ω

Adding is the series rule, not parallel.

RIGHT

R_t = 132 Ω (less than 220 Ω)

Parallel: R_t is less than the smallest resistor.

REAL ENGINEERING · KINLOCH STATION LIGHTING

After rewiring, each platform lamp at Kinloch (fictional) is on its own branch. Each gets the full 230 V.

If one lamp fails, the others stay lit. The supply current is the sum of all the lamp currents, so engineers size the cable for the total.



PROBE · QUICK CHECKS

1. In parallel, is the voltage across each branch the same? _____
2. I_1 = 2 A, I_2 = 3 A. I_t? _____
3. Two 4 Ω in parallel. R_t? _____

Parallel circuits and Kirchhoff's 1st law

EXAM READY · 7 MARKS

1 **State** Kirchhoff's 1st law. **[1]**

2 2.2 kΩ and 4.7 kΩ are in parallel. **Calculate** the total resistance. **[2]**

3 The pair in Q2 is connected to 9.0 V. **Calculate** the current in the 2.2 kΩ branch. **[2]**

4 **Explain** why adding another branch in parallel increases the supply current. **[2]**