E2.5 Combined circuits and LED resistors

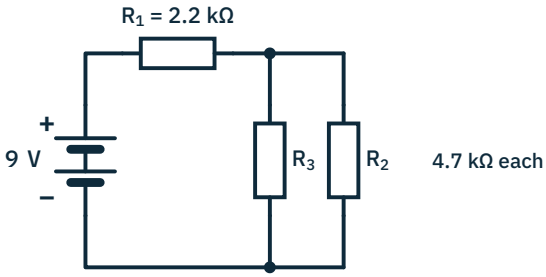
LEARNING INTENTION

We are learning to solve circuits with series and parallel parts, and to choose a series resistor for an LED.

SUCCESS CRITERIA – I CAN

- ☐ reduce a parallel part to one resistance, then add the series part
- ☐ find currents and voltages in a combined circuit
- ☐ calculate the series resistor for an LED
- ☐ choose a suitable standard resistor value

Combined circuits



R_1 in series with a parallel pair

A **combined circuit** has series and parallel parts.

1. Replace the parallel part with one resistor, R_p.
2. Add the series parts: $R_t = R_1 + R_p$.
3. Use V = IR for the total current, then work back to each part.

DATA BOOKLET page 5

$R_t = R_1 + R_2 + \ldots$
series

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

$V_t = V_1 + V_2$
Kirchhoff's 2nd law

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

$V = IR$
Ohm's law

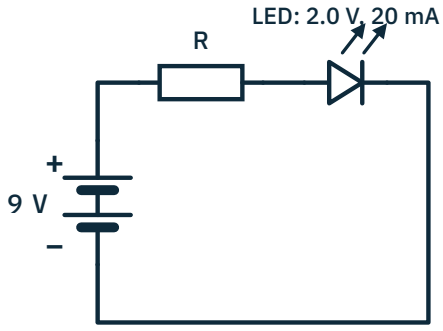
WORKED EXAMPLE A combined circuit

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
$V_s = 9.0$ V $R_1 = 2.2$ kΩ (series) $R_2 = R_3 = 4.7$ kΩ (parallel)	I_t and V across the parallel pair	$R_p = R_2 \times R_3 / (R_2 + R_3)$ $R_t = R_1 + R_p$ $I = V/R$	$R_p = 22.09 \div 9.4 = 2.35$ kΩ $R_t = 2.2 + 2.35 = 4.55$ kΩ $I_t = 9.0 \div 4.55 = 1.98$ mA $V_1 = 1.98 \times 2.2 = 4.35$ V	**$I_t = 1.98$ mA** $V_p = 9.0 - 4.35 = 4.65$ V

Each 4.7 kΩ branch carries half the current: about 0.99 mA.

Combined circuits and LED resistors

LEDs need a series resistor



LED with series resistor

An LED needs only about 2 V and a small current (around 20 mA). Too much current destroys it.

A **series resistor** limits the current. It takes the rest of the supply voltage (Kirchhoff's 2nd law).

WORKED EXAMPLE **Series resistor for an LED**

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 9.0 V LED: 2.0 V at 20 mA	R	$V_R = V_s - V_{LED}$ R = V/I	V_R = 9.0 − 2.0 = 7.0 V R = 7.0 ÷ 0.02	**R = 350 Ω** use 390 Ω (E12)

Choose the next value **up** so the current stays at or below 20 mA.

SHORT CIRCUIT

× WHAT EXAMINERS SAW

Asked why an LED in a series circuit would not light, answers said only 'it is broken'. Other pupils used the full supply voltage in R = V/I for an LED resistor.

✓ THE FIX

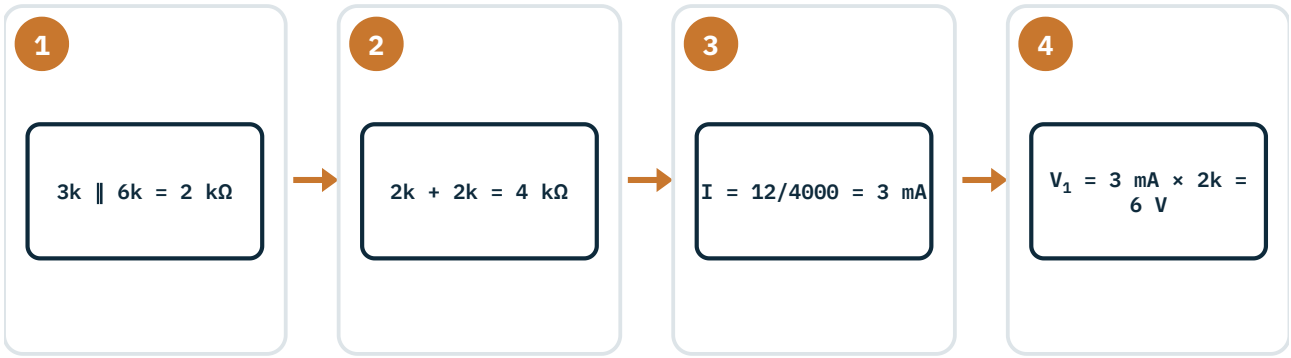
An LED may not light because it is the wrong way round, or because too little voltage is left for it. For the resistor, use only the voltage across the resistor: $V_s - V_{LED}$.

Course report 2026 Q3 (LED in a series circuit) and common LED-resistor errors.

Combined circuits and LED resistors

Solving combined circuits step by step

SOLVING A COMBINED CIRCUIT



1. Simplify the parallel part
2. Add the series part
3. Total current
4. Voltage across the series resistor

WORKED EXAMPLE Combined circuit current

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 12 V R_1 = 2 kΩ in series with 3 kΩ ∥ 6 kΩ	I_t	parallel first: R_p = 3×6/9 $R_t = R_1 + R_p$ $I = V/R_t$	R_p = 2 kΩ R_t = 4 kΩ I = 12/4000	**3 mA**

Always simplify the parallel part first.

WORKED EXAMPLE Choosing an E12 resistor for an LED

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 5 V LED 2.1 V at 15 mA	R and E12 value	$V_R = V_s - V_{LED}$ $R = V_R/I$ choose next E12 up	V_R = 2.9 V R = 2.9/0.015 = 193.3 Ω	**220 Ω (E12)**

Next value up keeps the current below the limit.

Combined circuits and LED resistors

WRONG

R = 193 Ω → choose 180 Ω

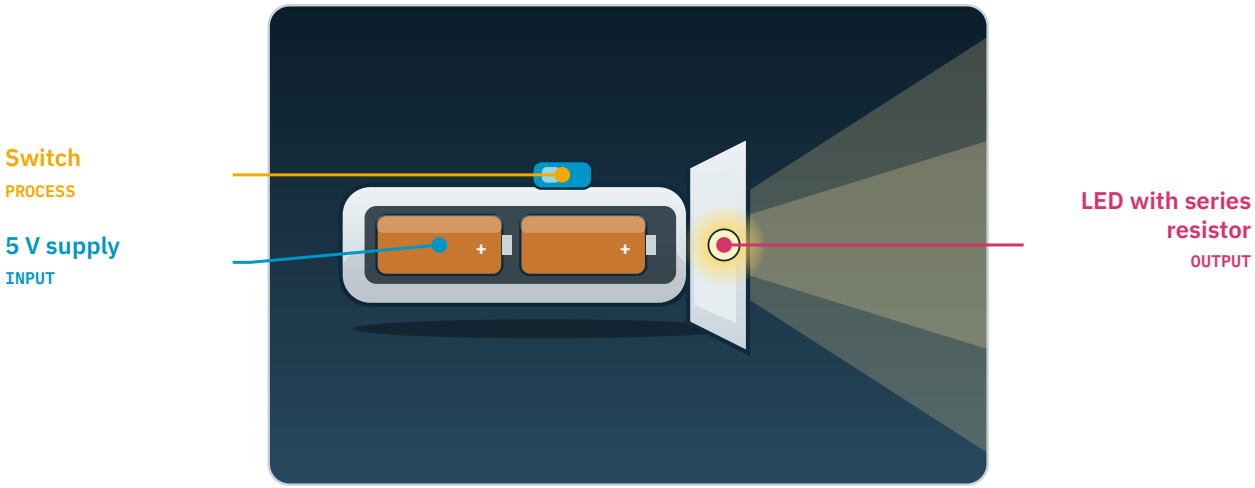
Value down: current too high, LED may fail.

RIGHT

R = 193 Ω → choose 220 Ω

Next E12 value UP: current stays safe.

LED torch (fictional Kinbrae Outdoor)



REAL ENGINEERING · PORT ARDMORE RAMP BEACONS

Each beacon at Port Ardmore (fictional) runs 12 LEDs from a 24 V supply. Engineers put LEDs in strings of four with one resistor per string.

Four LEDs at 3.2 V need 12.8 V, leaving 11.2 V for the resistor. At 20 mA: R = 11.2 ÷ 0.02 = 560 Ω, an E12 value.



Combined circuits and LED resistors

PROBE · QUICK CHECKS

1. First step for a combined circuit? _____
2. LED 2 V, supply 5 V. Voltage across the resistor? _____
3. Should you round an LED resistor up or down? _____

EXAM READY · 10 MARKS

1 A 1.0 kΩ resistor is in series with two 2.0 kΩ resistors in parallel. The supply is 6.0 V. **Calculate** the total current. **[3]**

2 An LED needs 2.1 V at 15 mA. The supply is 5.0 V. **Calculate** the series resistor. **[3]**

3 **State** the E12 value you would use for Q2, and **justify** your choice. **[2]**

4 An LED in a series circuit does not light. The battery is working. **State** two possible reasons. **[2]**