Series and parallel circuits

GCSE Physics · Electricity · Class handout

By the end of this lesson you should be able to:

- describe how current, potential difference and resistance behave in series and in parallel circuits
- use V = IR, Q = It, P = IV, P = I²R and E = Pt in calculations
- explain why adding resistors in parallel lowers the total resistance

1. Key quantities and equations

Quantity	Symbol	Unit
Current (rate of flow of charge)	I	ampere, A
Potential difference	V	volt, V
Resistance	R	ohm, Ω
Charge flow	Q	coulomb, C
Time	t	second, s
Power	P	watt, W
Energy transferred	E	joule, J

Charge flow = current × time (Q = It). Potential difference = current × resistance (V = IR). Power = potential difference × current (P = IV), which can also be written as P = I²R. Energy transferred = power × time (E = Pt).

2. Series circuits

In a series circuit, the components are connected one after another in a single loop, so there is only one path for the charge.

- The current is the same at every point in the loop.
- The potential difference of the supply is shared between the components.
- The total resistance is the sum of the individual resistances: $R_{total} = R_1 + R_2$.

Worked example 1. A 6.0 V battery is connected in series with a 4.0 Ω resistor and an 8.0 Ω resistor. The total resistance is 4.0 + 8.0 = 12 Ω. The current is I = V ÷ R = 6.0 ÷ 12 = 0.50 A, and it is the same through both resistors. The potential difference across the 4.0 Ω resistor is V = IR = 0.50 × 4.0 = 2.0 V, and across the 8.0 Ω resistor it is 0.50 × 8.0 = 4.0 V. Check: 2.0 V + 4.0 V = 6.0 V, the supply potential difference.

The power in the 4.0 Ω resistor is P = IV = 0.50 × 2.0 = 1.0 W. In 60 seconds it transfers E = Pt = 1.0 × 60 = 60 J of energy. P = I²R gives the same answer: 0.50² × 4.0 = 1.0 W. The charge that flows in that time is Q = It = 0.50 × 60 = 30 C.

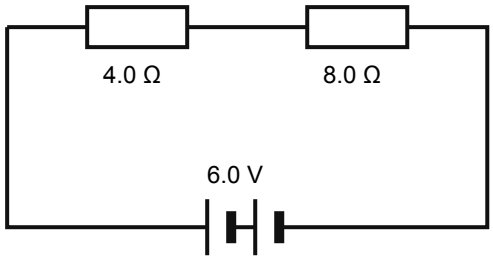


Figure 1: the series circuit in worked example 1.

3. Parallel circuits

In a parallel circuit, the components are connected in separate branches, so there is more than one path for the charge.

- The potential difference across each branch is the same as the supply potential difference.
- The total current is the sum of the currents through the separate branches.
- The total resistance of two resistors in parallel is less than the resistance of the smaller of the two.

Why does adding a resistor in parallel lower the total resistance? The new branch gives the charge another path. The supply potential difference stays the same, but more current flows from the supply in total, so the total resistance (V ÷ I) is lower.

Worked example 2. A 6.0 V battery is connected to two 6.0 Ω resistors in parallel. Each resistor has the full 6.0 V across it, so the current in each branch is I = V ÷ R = 6.0 ÷ 6.0 = 1.0 A. The total current from the battery is 1.0 + 1.0 = 2.0 A. The total resistance is R = V ÷ I = 6.0 ÷ 2.0 = 3.0 Ω, which is less than 6.0 Ω.

4. Series and parallel compared

	Series	**Parallel**
Current	The same everywhere	Splits between branches. The total is the sum of the branch currents
Potential difference	Shared between components	The same across each branch
Total resistance	The sum of the resistances	Less than the smallest single resistance
If one lamp breaks	The current stops, so every lamp goes out	The other branches still work

5. Common mistakes

- Saying current is "used up" by a component. The current is the same before and after a component in series. The charge transfers energy to the component, but the current stays the same.
- Adding parallel resistances like series ones. Two 6.0 Ω resistors in parallel give 3.0 Ω, not 12 Ω.
- Forgetting units, or using time in minutes. In Q = It and E = Pt, time must be in seconds.

Check your understanding

1. A 12 V supply is connected in series with a 2.0 Ω resistor and a 4.0 Ω resistor. Calculate the current in the circuit.
2. Explain why the lights in a house are connected in parallel rather than in series.
3. A 3.0 Ω resistor and a 6.0 Ω resistor are connected in parallel. Without calculating the total, explain why their total resistance must be less than 3.0 Ω.