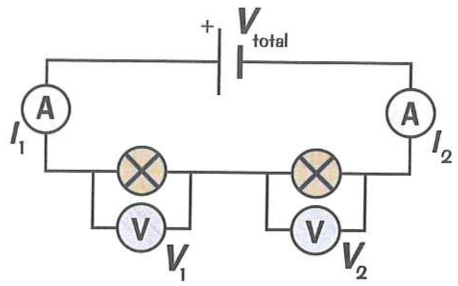
Series and Parallel Circuits

Make sure you know the rules about what happens to current and p.d. in series and parallel circuits. You can find out how and why the resistance changes for both of these circuits over on the next page.

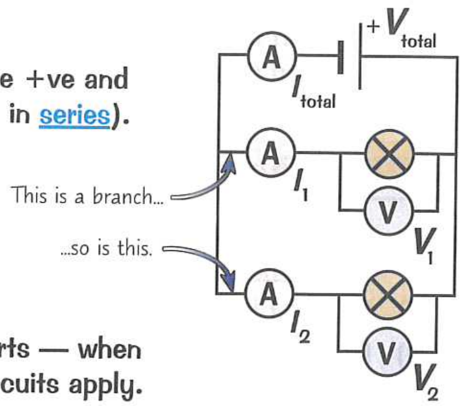
Series Circuits — All or Nothing



1) In series circuits, the different components are connected in a line, end to end, between the +ve and –ve of the power supply (except for voltmeters, which are always connected in parallel, but they don't count as part of the circuit).
2) If you remove or disconnect one component, the circuit is broken and they all stop working. This is generally not very handy, and in practice very few things are connected in series.
3) You can use the following rules to design series circuits to measure quantities and test components. For a series circuit:

- There's a bigger supply p.d. when more cells are in series (if they're all connected the same way). E.g. when two batteries with a p.d. of 1.5 V are connected in series they supply 3 V between them.
- The current is the same everywhere. $I_1 = I_2 = I_3$ etc. The size of the current depends on the total p.d. and the total resistance of the circuit ($I = V \div R$).
- The total potential difference of the supply is shared between components. The p.d. for each component depends on its resistance.
- The total resistance of the circuit increases as you add resistors (see next page).

Parallel Circuits — Everything is Independent



1) In parallel circuits, each component is separately connected to the +ve and –ve of the supply (except ammeters, which are always connected in series).
2) If you remove or disconnect one of them, it will hardly affect the others at all.
3) This is obviously how most things must be connected, for example in cars and in household electrics. You have to be able to switch everything on and off separately.
4) Everyday circuits often contain a mixture of series and parallel parts — when looking at components on the same branch the rules for series circuits apply.
5) For a parallel circuit:

- The potential difference is the same across all components. $V_1 = V_2 = V_3$ etc.
- Current is shared between branches. The total current flowing around the circuit is equal to the total of all the currents through the separate components. $I_{total} = I_1 + I_2$ etc.
- In a parallel circuit, there are junctions where the current either splits or rejoins. The total current going into a junction has to equal the total current leaving. (If two identical components are connected in parallel then the same current will flow through each component.)
- The total resistance of the circuit decreases if you add a second resistor in parallel (see p.189).

Series circuits — they're no laughing matter...

Get those rules straightened out in your head, then have a go at these questions to test what you can remember.

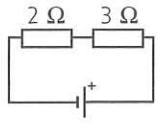
Q1 A filament lamp and a resistor are connected in series. A current of 0.5 A flows through the lamp. State the current flowing through the resistor. [1 mark]

Q2 Draw a circuit diagram for two filament lamps connected in parallel to a battery. Both of the lamps can be switched on and off without affecting each other. [3 marks]

More on Series and Parallel Circuits

Time for a bit more about series and parallel circuits, including a quick experiment. Fun, fun, fun...

Adding Resistors in Series Increases Total Resistance



Total resistance = 5 Ω

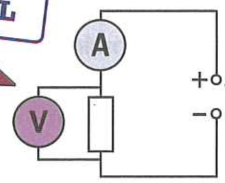
1) In series circuits the total resistance of two components is just the sum of their resistances.
2) This is because by adding a resistor in series, the two resistors have to share the total p.d.
3) The potential difference across each resistor is lower, so the current through each resistor is also lower. In a series circuit, the current is the same everywhere so the total current in the circuit is reduced when a resistor is added. This means the total resistance of the circuit increases.
4) The bigger a component's resistance, the bigger its share of the total potential difference.

Adding a Resistor in Parallel Reduces the Total Resistance

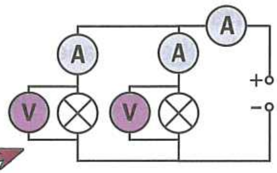
1) If you have two resistors in parallel, their total resistance is less than the resistance of the smallest of the two resistors.
2) This can be tough to get your head around, but think about it like this:
   - In parallel, both resistors have the same potential difference across them as the source.
   - This means the 'pushing force' making the current flow is the same as the source p.d. for each resistor that you add.
   - But by adding another loop, the current has more than one direction to go in.
   - This increases the total current that can flow around the circuit. Using $V = IR$, an increase in current means a decrease in the total resistance of the circuit.

Use a Circuit to Investigate these Properties

PRACTICAL



1) Set out the circuit shown in the diagram on the right.
2) Vary the output potential difference from the power supply. Record the readings from the ammeter and voltmeter for each change.
3) Replace the resistor with a filament lamp and repeat step 2.
4) Now, connect a second filament lamp to the circuit, in parallel to the first. Connect ammeters and a second voltmeter, so you have:



5) Again, vary the output potential difference of the supply.
6) Write down the current through each ammeter and the p.d. across each component.

You can also add more resistors to this circuit to see how potential difference is shared across components in series and how the increased resistance affects the current through the circuit.

For the series circuit, you should find that as the potential difference increases, the current through the resistor increases. (Using $V = IR$ from page 185 — R for a fixed resistor is constant, so an increase in V causes an increase in I.) You should find a similar, but non-linear relationship between p.d. and current for a filament bulb (see p.187).

For the parallel circuit, you should find that as p.d. increases, so does the current through each bulb (again, this is a non-linear relationship). The p.d. across each bulb is the same as the p.d. of the power supply. You should also notice that the total current through the circuit is the sum of the current through the two branches and that this is larger than the total current through the series circuit with one filament bulb (the overall resistance of the parallel circuit is lower, see above — $V = IR$, so a lower value of R causes a higher value of I).

A current shared (between identical components) *— is a current halved...*

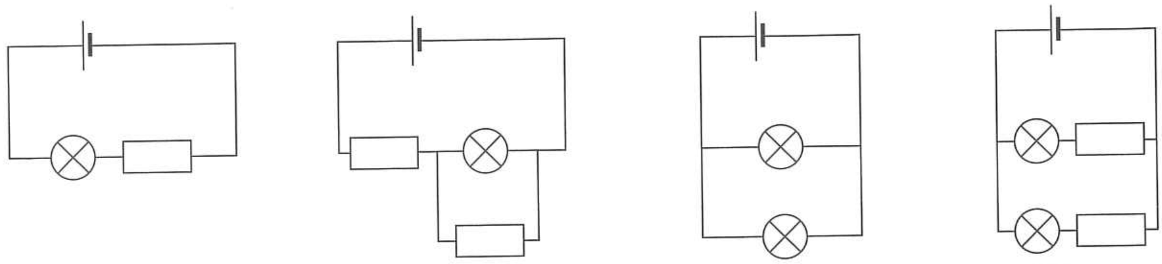
Parallel circuits are more complicated than series circuits but you need to learn about both I'm afraid.

Q1 A 12 V cell is connected in series with a 2 Ω resistor, a 3 Ω resistor and a 7 Ω resistor. Calculate the current through the circuit. [3 marks]

Series and Parallel Circuits

1 **Figure 1** shows a number of circuits. Tick the box below the diagram that shows all the components connected in series. Grade 4-6

Figure 1



☐ A ☐ B ☐ C ☐ D

[Total 1 mark]

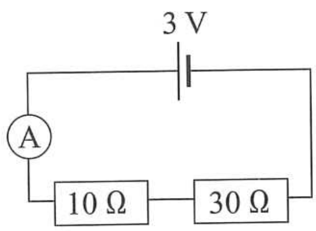
2 Draw a circuit diagram consisting of a cell and two LDRs connected in parallel. Grade 4-6

[Total 2 marks]

3 In the circuit in **Figure 2**, the reading on the ammeter is 75 mA. Grade 6-7

a) Calculate the total resistance of the two resistors.

Figure 2



Resistance = ... Ω
[1]

b) Calculate the potential difference across the 30 Ω resistor.

Potential Difference = ... V
[3]

[Total 4 marks]

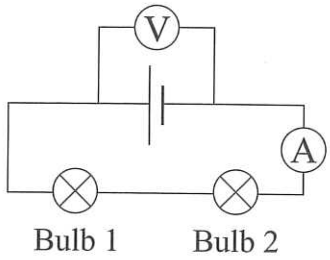
4* Explain why adding resistors in series with each other increases the total resistance of the resistors, whilst adding resistors in parallel with each other decreases the total resistance of the resistors. Grade 7-9

[Total 6 marks]

PRACTICAL

5 A student is investigating series and parallel circuits, using bulbs which are labelled as having the same resistance. She sets up the circuit shown in **Figure 3**. Grade 7-9

Figure 3



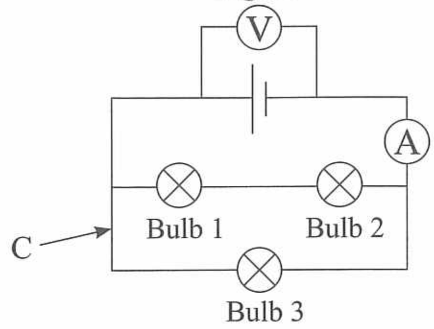
The voltmeter reads 12 V and the ammeter reads 0.25 A.
The student uses these values to calculate the resistance of each bulb.

a) Calculate the resistance of each bulb, assuming that the bulbs do have the same resistance.

Resistance = ... Ω
[3]

b) The student then adds a third bulb to the circuit, as shown in **Figure 4**.

Figure 4



i) Assuming that bulb 3 is identical to bulbs 1 and 2, find the new current through the ammeter.

Current = ... A
[2]

ii) The student observes that bulb 3 is brighter than bulbs 1 and 2. Explain why.

....

....
[2]

c) The student then adds a resistor to the circuit in **Figure 4**, at the point marked C.

i) Describe the effect of this on the current through the ammeter.

....
[1]

ii) State how this affects the brightness of the three bulbs.

....

....
[2]

d) When the student's teacher marks her experiment, he says she should have measured the potential difference across and the current through each bulb throughout the experiment. Give **two** reasons why.

....

....

....
[2]

[Total 12 marks]

Exam Practice Tip

Although we talk about series and parallel circuits as separate things, real circuits are often a mix — you might get a question where some components are connected in series with each other, but where there's more than one branch to the circuit. Don't panic, just remember that the rules of parallel circuits apply when you're looking at the different branches, and the rules of series circuits apply when you're looking at the components connected along one branch.