Series and Parallel Circuits

SO FAR WE HAVE been working with a simple DC circuit wired in series. We have also looked at what happens when resistors are wired in series and in parallel. The Intermediate exam specification requires you to understand a little more about the potential differences and currents in series and parallel circuits. Let's recap on what we have learned already.

Series circuits (3b.1)

YOU SHOULD ALREADY have constructed a simple DC circuit with a bulb, a resistor, a switch and a battery (see **Fig 36**). All the components were wired in series to form the circuit that allowed the bulb to light when the switch was closed.

In worksheet 9 you measured the potential difference across the various components and found that the potential differences across the bulb and the resistor added up to the potential difference across the battery. We noted that the total potential difference is divided between the components in a series circuit.

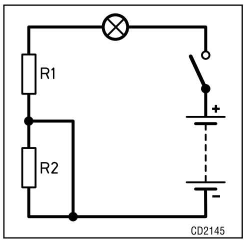

Fig 36: Circuit diagram of the simple DC circuit.

In worksheet 10 you measured the current flowing through the series circuit and found that the current was the same no matter where you measured it.

We have also looked at resistors, in worksheet 14, and we found that when resistors are connected in series the overall resistance in the circuit increases.

Following on from this point, you should be able to deduce that adding more resistance to a series circuit will divide the potential difference further, so there is less across each component, and the current flowing through all the components in the circuit will reduce.

If you need convincing about this, try removing the shorting strap from the 470Ω resistor on your DC circuit and measuring the potential difference across each of the two resistors and the bulb then measure the current flowing through the series circuit. You should find that the potential difference across the battery terminals has been divided between the two resistors and the bulb and that the current has reduced to the point that the bulb no longer lights; although current is still flowing through the bulb, not enough energy is being transferred to make the filament wire white hot.

The two-step calculation explained in Worksheet 19 could be of value in calculating potential differences in series circuits and knowing that series resistors add up to a single combined value should allow you to use Ohm's law to work out current or potential difference.

There is not much more to say about series circuits, we have covered how the potential difference divides and how the current is exactly the same throughout the circuit.

Parallel circuits (3b.1)

WHEN YOU CONNECTED two identical resistors in parallel in worksheet 14, the overall resistance halved. We noted that this was because the current had two paths to follow so the overall opposition to the current flow was reduced; in other words, if we connect resistors in parallel they present less resistance than a single resistor.

If you think a little more about this it becomes quite clear why this is. The potential difference across the two resistors is exactly the same, it has to be because they are connected to the same points, their own resistance has not changed, so Ohm's law can be used to show that the current through each of them is the same as it would have been had there been just one resistor in the same circuit.

Not convinced? Let's try an example. Suppose we connect a 50 resistor across a 10V battery. Using the Ohm's law triangle, the current (I) through the resistor (R) will be = V / R = 10 / 50 = 0.2A, or 200mA. If we add a second 50Ω resistor in parallel it will have the same current flowing through it because it too will have 10V across it and it is still a 50Ω resistor (see **Fig 37**).

So, if there is 200mA flowing through each resistor, the total current flowing in the circuit must be 400mA; the combination of the current flowing through each resistor. If we then use Ohm's law, knowing that there is a 10V potential difference and a 400mA current, the total resistance in the circuit works out as 25Ω (R = V / I = 10 / 0.4 = 25), proving that the total resistance presented by two equal resistors in parallel is half of their individual value.

Looking at this another way, because the potential difference was the same across both the resistors, the total current flowing in the circuit was divided between the parallel components. This would be true no matter how many components were connected in parallel – if there were four resistors and a bulb the current would be divided between all five components.

It is worth noting that the halving of resistance and doubling of current only works when the parallel resistors are the same value; parallel circuits using different values are Advanced level material.

An optional practical exercise

IF YOU WOULD like to prove this theory for yourself, here is a short practical exercise for you to try. This is not one of the assessed activities but it might just help to bring the theory to life.

1. Set the DC circuit to the original configuration (shorting wire across the 470Ω resistor).
2. Close the switch and measure the potential difference between A and E (across the bulb and R1 as shown in **Fig 38**). Note it down.
3. Open the switch and measure the current by inserting your meter between B and C (as shown in **Fig 38**). Note it down.

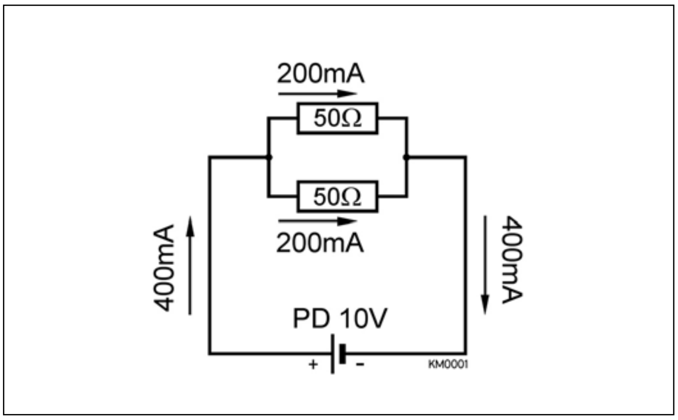

Fig 37: The total current is divided between parallel components. Ohm's law can be used to calculate the current in each one.

4. Using Ohm's law, work out the combined resistance of the bulb and the resistor.
5. Now solder a resistor of the same value, or one very close to it, between A and E, in parallel with the bulb and R1. (See **Fig 38)**.
6. Repeat steps 2 and 3 and note down your measurements. Also take note to see if the bulb is any brighter, dimmer, or just the same.
7. Apply you new measurements to Ohm's law to see what the new resistance is.

If you have carried out the steps correctly you should find that the potential difference across A and E did not change when you added the second resistor in parallel with the bulb and R1 but the current should have doubled and the overall resistance value should have halved. The brightness of the bulb should not have been affected by the additional resistance as the current through that part of that parallel circuit had not changed.

A domestic example

FROM WHAT YOU now know, it should come as no surprise to learn that household light bulbs are wired in parallel; switching extra lights on does not add additional resistance to the circuit and make them all dim. Furthermore, if one of the light bulbs fails and goes 'open circuit' the others still work, if they were wired in series the open circuit would prevent current flowing through the other bulbs and none would light.

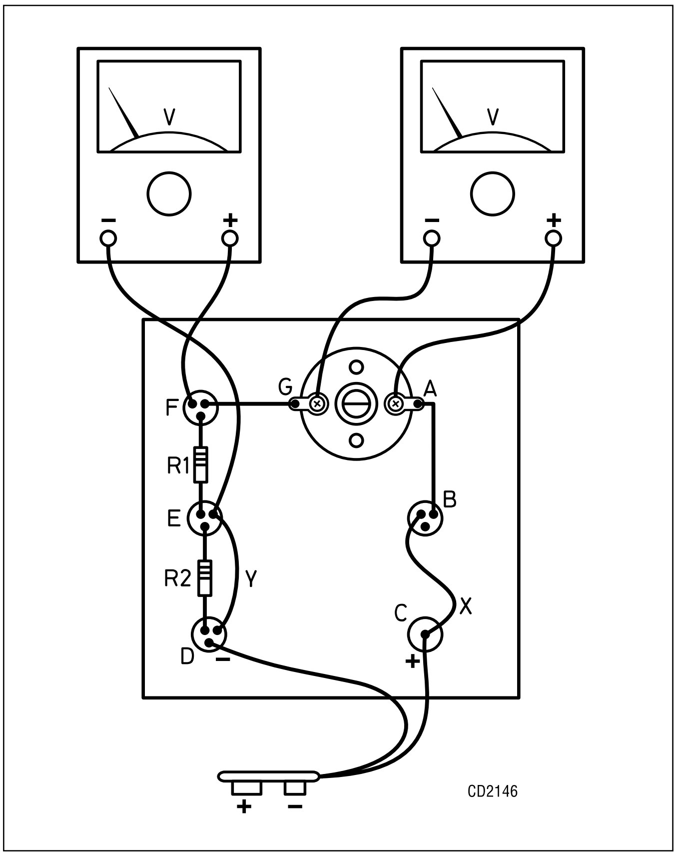

Fig 38: DC test circuit modified for parallel measurements

Summary

SOME KEY LEARNING points for you to remember:

- In a series circuit, the total potential difference across it is divided between the components that make up the circuit but the current is the same through each component.
- In a parallel circuit, the total potential difference applied to the circuit is that same across each component but the current is divided between the components that make up the circuit.
- Using this information and Ohm's law you can calculate potential differences and currents in series and parallel circuits.
- Resistors in series and parallel circuits can be used to set potential differences and currents, for example for semiconductor biasing.