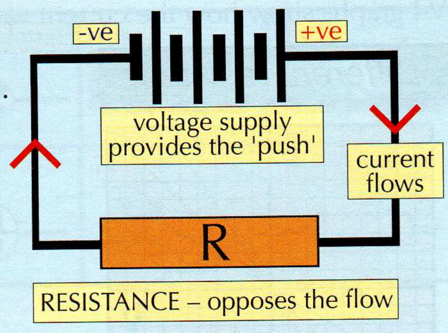
Circuits — the Basics

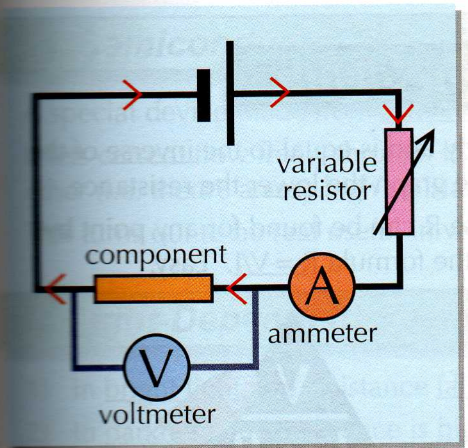
You can use a test circuit to work out the resistance of just about anything. But first, the basics...

1) Current (I, measured in A) is the flow of electrons round the circuit, which only happens if there's a voltage.
2) Voltage (in V) is the driving force that pushes the current round.
3) Resistance (in Ω) is anything in the circuit which slows the flow down.
4) There's a balance: the voltage tries to push the current round the circuit, and the resistance opposes it — the relative sizes of voltage and resistance decide how big the current will be:
   - If you increase the voltage, more current will flow.
   - If you increase the resistance, less current will flow. *(or more voltage is needed for the same current).*



The standard test circuit

This is without doubt the most totally bog-standard circuit the world has ever known. So learn it.



The ammeter

1) Measures the current flowing through the component.
2) Must be placed in series (see pages 94-95).
3) Can be put anywhere in series in the main circuit, but never in parallel like the voltmeter.

The voltmeter

1) Measures the voltage across the component.
2) Must be placed in parallel (see pages 96-97) around the component under test (not the variable resistor or battery).
3) The proper name for 'voltage' is 'potential difference' (P.D.).

Five important points

1) This very basic circuit is used for testing components, and for getting V-I graphs for them (see next page).
2) The component, the ammeter and the variable resistor are all in series, which means they can be put in any order in the main circuit. The voltmeter, on the other hand, can only be placed in parallel around the component under test, as shown.
3) As you vary the variable resistor it alters the current flowing through the circuit.
4) This allows you to take several pairs of readings from the ammeter and voltmeter.
5) You can then plot these values for current and voltage on a V-I graph.

The current is always shown flowing from positive to negative

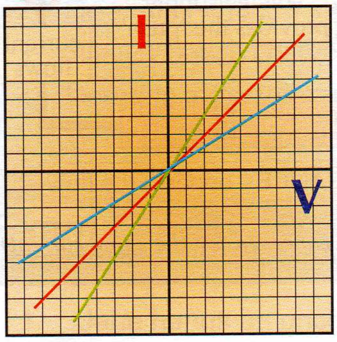
The funny thing is — the electrons in circuits actually move from –ve to +ve... but scientists always think of current as flowing from +ve to –ve. Basically it's just because that's how the early physicists thought of it (before they found out about the electrons), and now it's become convention.

Resistance and V = I × R

*Three hideously important **voltage-current graphs***

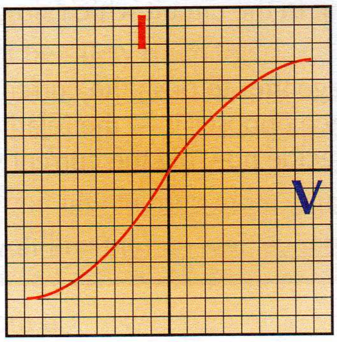
V-I graphs show how the current varies as you change the voltage. Learn these three really well:

Different resistors



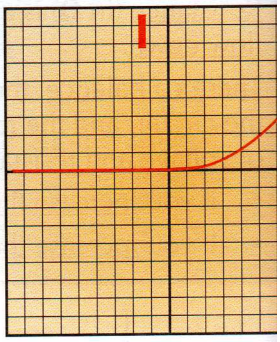
The current through a <u>resistor</u> (at constant temperature) is <u>proportional to voltage</u>. <u>Different resistors</u> have different <u>resistances</u>, hence the different <u>slopes</u>.

Filament lamp



As the <u>temperature</u> of the filament <u>increases</u>, the <u>resistance increases</u>, hence the <u>curve</u>.

Diode



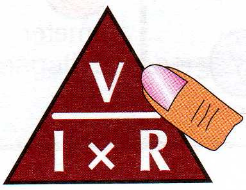
Current will only flc through a diode <u>in c direction</u>, as shown

*Calculating resistance: **R = V ÷ I**, (or **R = "1/gradient"**)*

For the <u>straight-line graphs</u> the resistance of the component is <u>steady</u> and is equal to the <u>inverse</u> of t <u>gradient</u> of the line, or "<u>1/gradient</u>". In other words, the <u>steeper</u> the graph the <u>lower</u> the resistance. If the graph <u>curves</u>, it means the resistance is <u>changing</u>. In that case R can be found for any point b taking the <u>pair of values</u> (V, I) from the graph and sticking them in the formula <u>R = V/I</u>. Easy.

Resistance = Potential Difference / Current

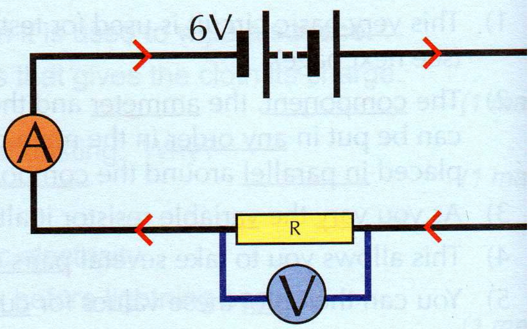
$$\text{Resistance} = \frac{\text{Potential Difference}}{\text{Current}}$$



*Calculating resistance — **an example***

<u>EXAMPLE</u>. Voltmeter V reads 6 V and resistor R is 4 Ω. What is the current through Ammeter A?

<u>ANSWER</u>. Use the formula V = I × R. We need to find I, so the version we need is I = V/R. The answer is then: 6/4 which is <u>1.5 A</u>.

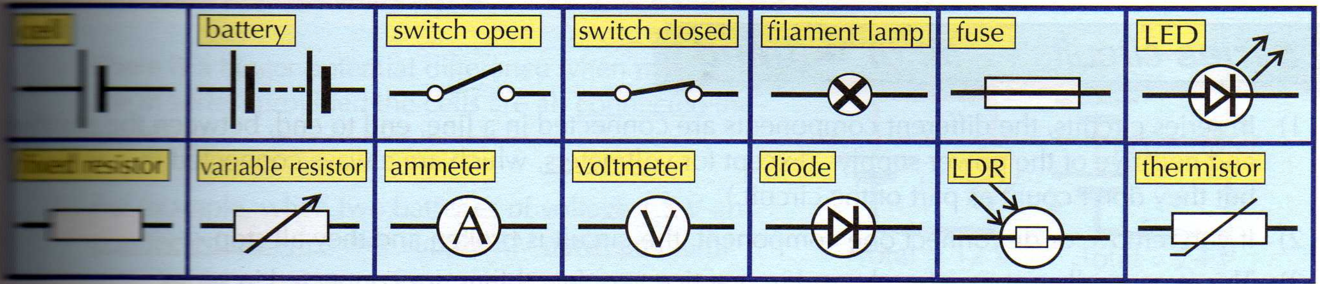


You have to be able to interpret V-I graphs for your exam

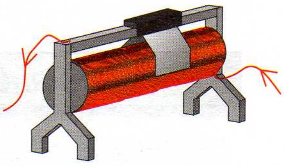
Remember — the <u>steeper</u> the <u>slope</u>, the <u>lower</u> the <u>resistance</u>. And you need to know that equation inside out, back to front and upside down too — it's really useful and important.

Circuit Symbols and Devices

Circuit symbols you should know:



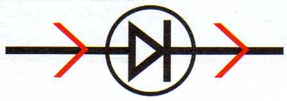
1) Variable resistor



1) A resistor whose resistance can be changed by twiddling a knob or something.
2) The old-fashioned ones are huge coils of wire with a slider on them.
3) They're great for altering the current flowing through a circuit. Turn the resistance up, the current drops. Turn the resistance down, the current goes up.

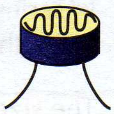
2) "Semiconductor diode" or just "diode"

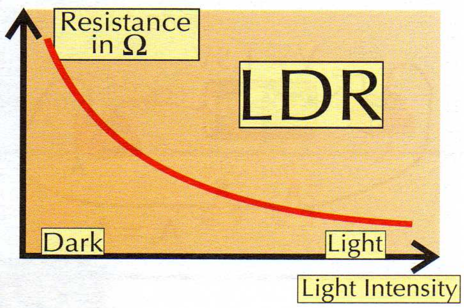
A special device made from semiconductor material such as silicon. It lets current flow freely through it in one direction, but not in the other (i.e. there's a very high resistance in the reverse direction). This turns out to be real useful in various electronic circuits.



3) Light-Dependent Resistor or "LDR" to you

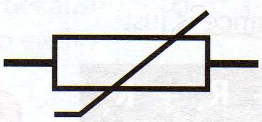
1) In bright light, the resistance falls.
2) In darkness, the resistance is highest.
3) This makes it a useful device for various electronic circuits, e.g. automatic night lights, burglar detectors.

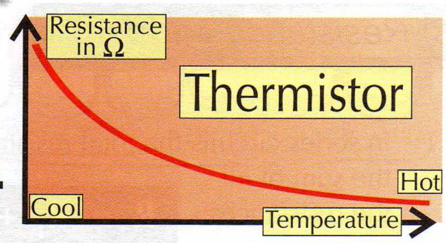




4) Thermistor (temperature-dependent resistor)

1) In hot conditions, the resistance drops.
2) In cool conditions, the resistance goes up.
3) Thermistors make useful temperature detectors, e.g. car engine temperature sensors and electronic thermostats.





Know what each of the circuit symbols represents

You have to learn those circuit symbols so you can read circuit diagrams in the exam. It's not too bad remembering how LDRs and thermistors behave — low light/heat means high resistance.

Series Circuits

You need to be able to tell the difference between series and parallel circuits just by looking at the[...] You also need to know the rules about what happens with both types. Read on.

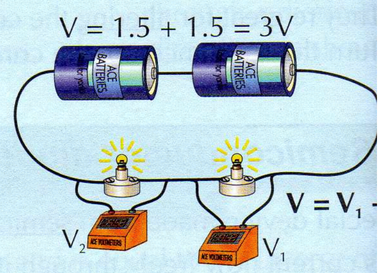
Series circuits — all or nothing

1) In series circuits, the different components are connected in a line, end to end, between the p[...] and negative of the power supply. (Except for voltmeters, which are always connected in para[...] 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.
3) This is generally not very handy, and in practice very few things are connected in series.

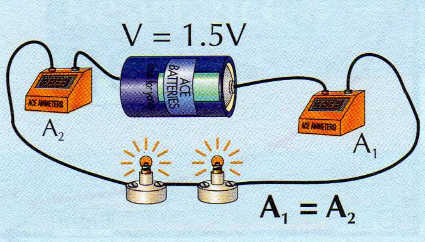
1) Potential difference is shared:

In series circuits the total P.D. of the supply is shared between the various components. So the voltages round a series circuit always add up to equal the source voltage:

$$V = V_1 + V_2 + V_3$$



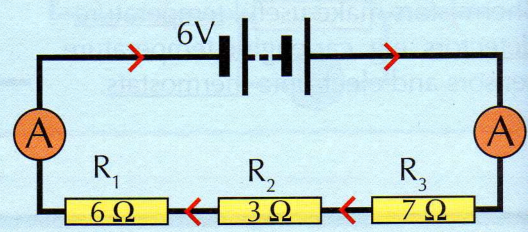
2) Current is the same everywhere:



1) In series circuits the same current flows through all parts of the circuit, i.e.: $A_1 = A_2$
2) The size of the current is determined by the total P.D. of cells and the total resistance of the circuit, i.e. I = V/R

3) Resistance adds up:

1) In series circuits the total resistance is just the sum of all the resistances: $R = R_1 + R_2 + R_3$
2) The bigger the resistance of a component, the bigger its share of the total P.D.

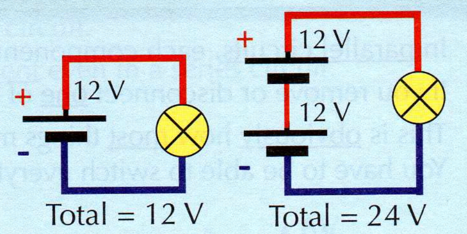


Total resistance = 6 + 3 + 7 = 16 Ω

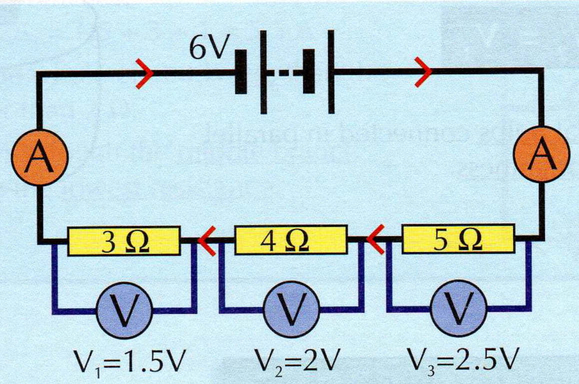
Series Circuits

Cell voltages add up:

1) There is a bigger potential difference when more cells are in series, provided the cells are all connected the same way.
2) For example, when two batteries of voltage 1.5 V are connected in series they supply 3 V between them.



Example of a series circuit



Voltages add to equal the source voltage: 1.5 + 2 + 2.5 = 6 V

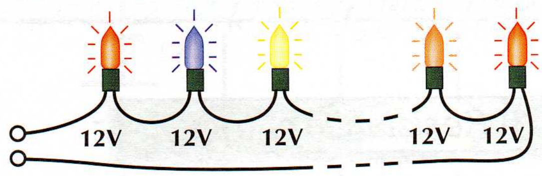
Total resistance is the sum of the resistances in the circuit: 3 + 4 + 5 = 12 ohms

Current flowing through all parts of the circuit = V/R = 6/12 = 0.5 A

(If an extra cell was added of voltage 3 V then the voltage across each resistor would increase.)

Christmas fairy lights are often wired in series

Christmas fairy lights are about the only real-life example of things connected in series, and we all know what a pain they are when the whole lot go out just because one of the bulbs is slightly dicky. The only advantage is that the bulbs can be very small because the total 230V is shared out between them, so each bulb only has a small voltage across it.



Series circuits aren't used very much in the real world

A lot of fairy lights are actually done on a parallel circuit these days — they have an adapter that brings the voltage down, so the lights can still be diddy but it doesn't matter if one of them blows.

Parallel Circuits

Parallel circuits are much more sensible than series circuits and so are much more common in real

Parallel circuits — *independence* and *isolation*

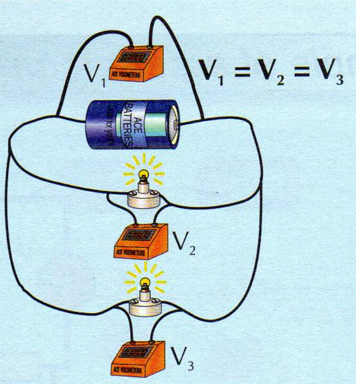
1) In parallel circuits, each component is separately connected to the +ve and –ve of the supply.
2) If you remove or disconnect one of them, it will hardly affect the others at all.
3) This is obviously how most things must be connected, for example in cars and in household ele
   You have to be able to switch everything on and off separately.

1) P.D. is the **same** across all components:

1) In parallel circuits all components get the full source P.D., so the voltage is the same across all components:

$$V_1 = V_2 = V_3$$

2) This means that identical bulbs connected in parallel will all be at the same brightness.

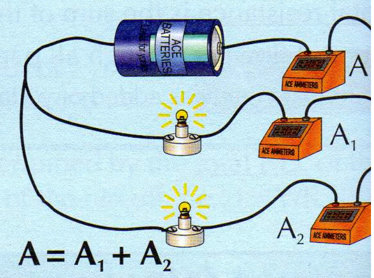


2) Current is **shared** between branches:

1) In parallel circuits the total current flowing around the circuit is equal to the total of all the currents in the separate branches.

$$A = A_1 + A_2 + A_3$$

2) 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 it.



3) If two identical components are connected in parallel, the same current flows through each c

3) Resistance is **tricky**:

1) The current through each component depends on its resistance. The lower the resistance, the bigger the current that'll flow through it.
2) The total resistance of the circuit is tricky to work out, but it's always less than that of the branch with the smallest resistance.

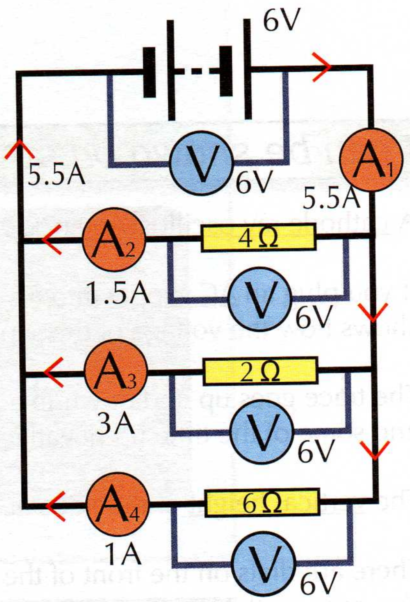
Parallel Circuits

Voltmeters and ammeters are exceptions to the rule:

1) Ammeters and voltmeters are exceptions to the series and parallel rules.
2) Ammeters are always connected in series even in a parallel circuit.
3) Voltmeters are always connected in parallel with a component even in a series circuit.

Example of a parallel circuit

1) The voltage across each resistor in the circuit is the same as the supply voltage. Each voltmeter will read 6 V.
2) The current through each resistor will be different because they have different values of resistance.
3) The current through the battery is the same as the sum of the other currents in the branches. i.e. $A_1 = A_2 + A_3 + A_4 \Rightarrow A_1 = 1.5 + 3 + 1 = 5.5$ A
4) The total resistance in the whole circuit is less than the lowest branch, i.e. lower than 2 Ω.
5) The biggest current flows through the middle branch because that branch has the lowest resistance.

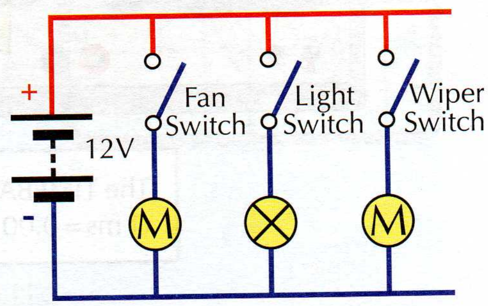


Everything electrical in a car is connected in parallel

Parallel connection is essential in a car to give these two features:

1) Everything can be turned on and off separately.
2) Everything always gets the full voltage from the battery.

The only slight effect is that when you turn lots of things on the lights may go dim because the battery can't provide full voltage under heavy load. This is normally a very slight effect. You can spot the same thing at home when you turn a kettle on, if you watch very carefully.



(M) is the symbol for a motor.

All the electrics in your house will be wired in parallel circuits

Parallel circuits might look a bit scarier than series ones, but they're much more useful — and you don't have to learn as many equations for them. Remember: each branch has the same voltage across it and the overall resistance is lower than that of the least resistant branch.