



ELECTRICAL INSTALLATION 1

CP4098

Inspiring The Next
Generation Of Engineers

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Introduction

The course aims to prepare you for Unit 107 - “Electrical Science and Technology” part of the City and Guilds Level 1 Diploma in Electrical Installation qualification. It assumes no prior knowledge of electricity.

As you work through the course, the layouts show you how to build the systems and each task provides guidance on how to test and investigate them. The activities include a mixture of practical investigations, supporting theory, calculations and opportunities to relate electrical principles to real-world applications.

For your records:

- It is important that you keep accurate records of what you do.
- A Student Handout will be issued to assist with these records.
- In addition, take whatever notes you feel are necessary to help with this.

Circuit Training

From the dictionary:

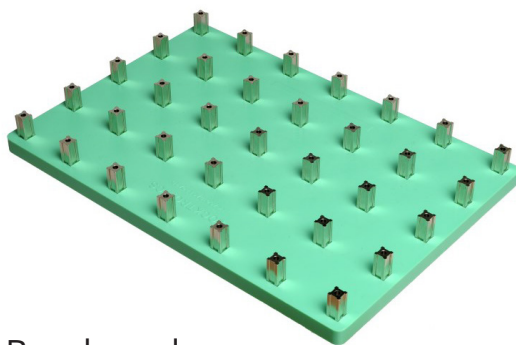
"Circuit: noun

- a roughly circular line, route, or movement that starts and finishes at the same place."

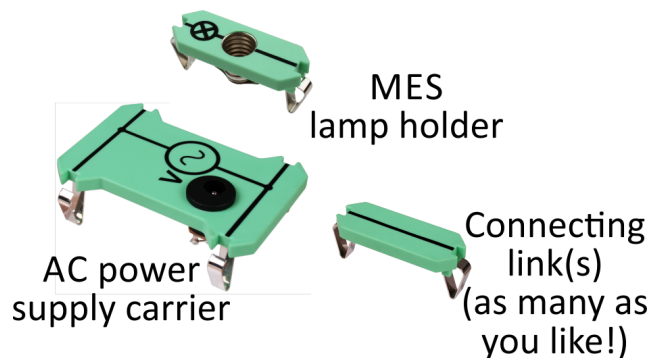
Build a circuit that makes a bulb light, using a 12V 0.1A bulb and the 12V AC power supply.



The hardware:



Baseboard



AC power
supply carrier

MES
lamp holder

Connecting
link(s)
(as many as
you like!)

Locktronics	Domestic Electricity
Bulb	Like a domestic bulb, but designed for lower voltage and current.
Connecting Links	The wires.
AC Power Supply Carrier	The consumer unit - where the domestic circuits connect to the National Grid.

Power Supplies

Power supply:

- Drives current around the circuit by applying a voltage.
- Has two terminals (connection points) one 'positive' the other 'negative';
- Current flows from the positive terminal to the negative terminal.

DC power supply - (DC = direct current):

- One terminal is always positive, the other always negative;
- 'One-way traffic' - current always flows the same way around the circuit.

AC power supply - (AC = alternating current):

- Terminals change polarity repeatedly, one positive, the other negative and then they swap;
- 'Two-way traffic' - current flows clockwise, then anticlockwise around the circuit.

AC or DC - which is used?

Each has its uses!

Electricity is usually generated and transmitted as AC. because:

- Alternators are generally more efficient than dynamos;
- 'Step-up' and 'step-down' transformers can modify voltage and current to allow more efficient distribution.

Electronic devices - mobile phones, computers, televisions etc. usually require DC.

AC power can be converted into DC using the processes of rectification and regulation.

DC power can be converted into AC using a device called an inverter.

DC power supplies:

- **Battery** - Chemical reactions generate DC voltages, e.g. 'lead-acid' batteries;
- **Solar cell** - Photo-voltaic cells convert light energy into DC electrical energy;
- **Dynamo** - A rotating coil of wire near a magnet generates DC provided a 'commutator' connects the coil to the rest of the circuit.

AC power supplies:

- **Alternator** - Another example of a rotating coil of wire near a magnet;
 - A 'slip-ring' connects to the rest of the circuit;
 - The coil can be rotated by high-pressure steam in a power station, by wind (wind- generator) or by falling water (hydro-electricity).

AC Versus DC

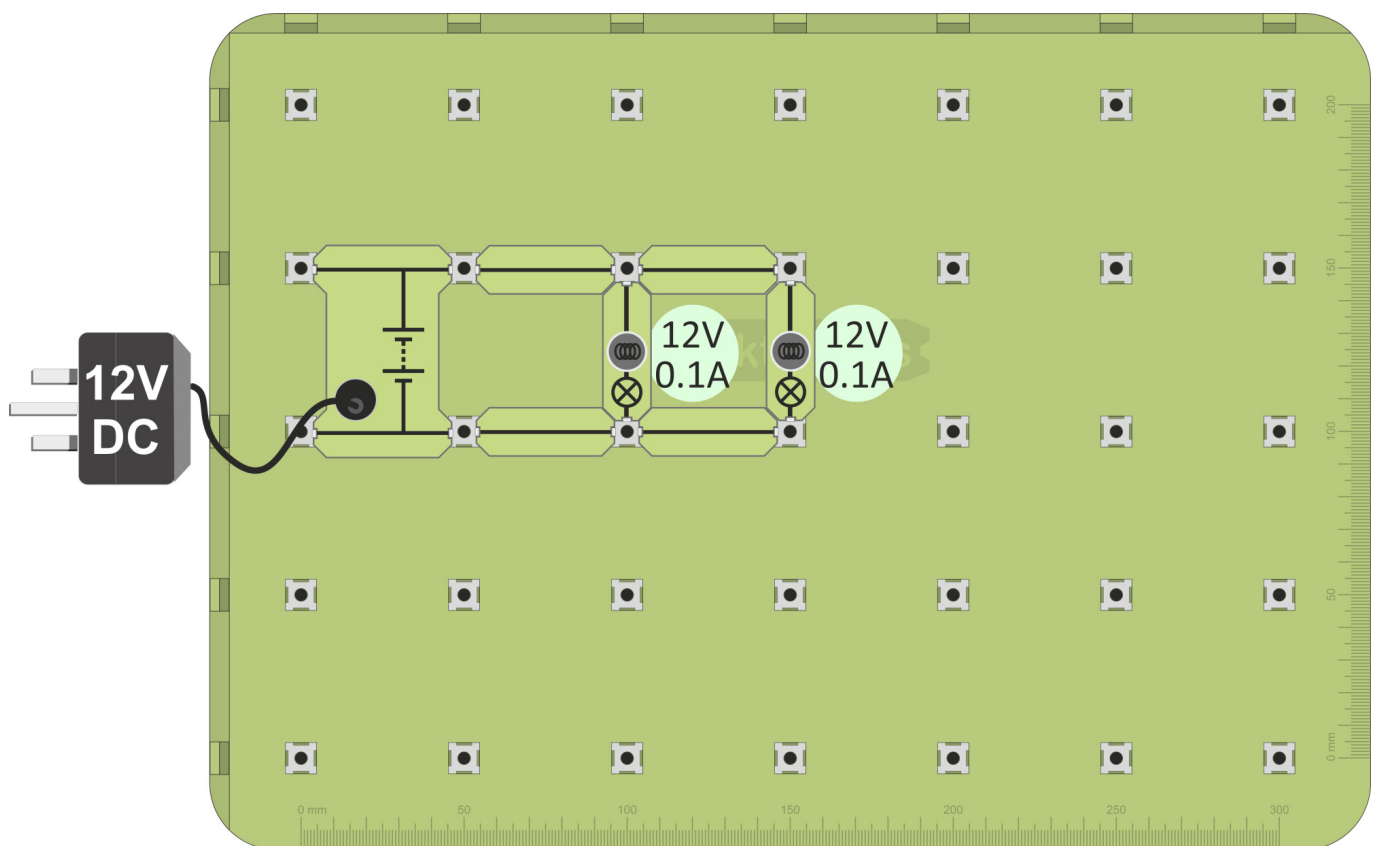
The aim of this and the next activity is to compare the performance of an AC and a DC power supply.

Preliminary experiment - finding two bulbs that have the same brightness.

Build the layout shown below.

The lamps are connected in parallel and should be equally bright.

If not, change the bulbs until you find two that are equally bright.

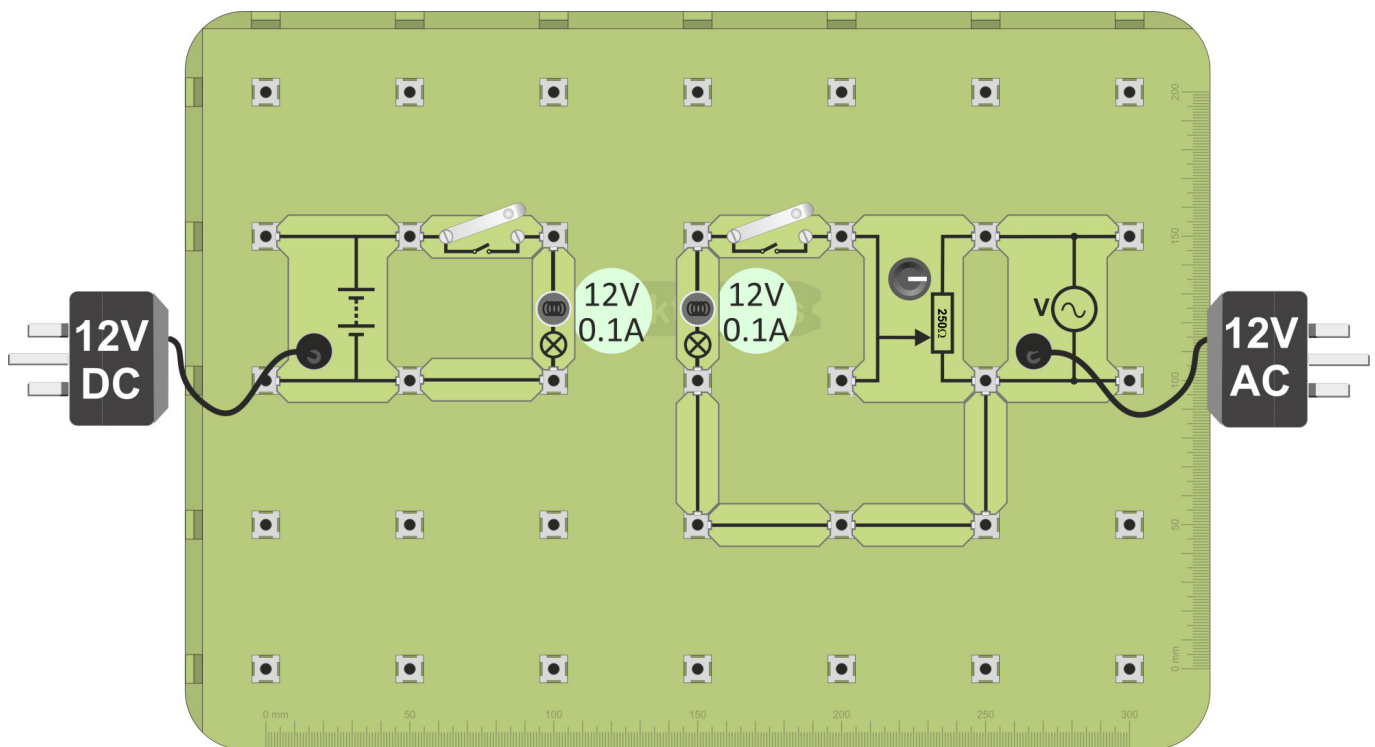


Use these bulbs in the next activity, which has two circuits, one lamp powered by DC, and an identical lamp powered by AC.

AC Versus DC

This activity continues the task of comparing the AC and DC power supply.

1. Build the layout shown below, using the two bulbs from the previous activity. There are two circuits, one lamp powered by DC, and an identical one powered by AC.
2. Connect the DC power supply, set to 12V, and the AC supply.
3. Switch both on.



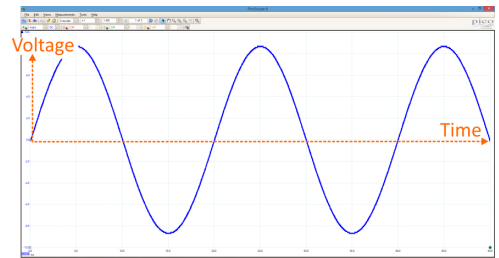
1. Adjust the 250Ω 'pot' until the two lamps have the same brightness. Now, the AC voltage has exactly the same effect as the DC supply.
2. Connect a multimeter, set to the 20V DC range, to read the voltage across the DC-powered lamp. This gives the rms value of the AC voltage.
3. Record the reading in the Student Handout.

AC and DC Again

Measuring AC signals often calls for the use of an oscilloscope, which produces a voltage / time graph of the signal.

The diagram shows an example - the output of an AC power supply.

Voltage and time axes are shown in orange.



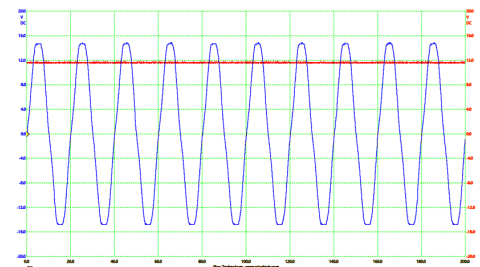
Notice:

- The average voltage is zero - the voltage is positive for half of the time and negative for half of the time;
- It may be described as a peak voltage of 9V, but most of the time the voltage is much less.

So what is the “average” effect of an AC supply? How can we compare AC and DC?

The previous experiment gives the answer - look for the two having the same effect on a device like a bulb. The oscilloscope trace opposite shows the AC and DC power supply signals from that experiment, when the two bulbs had the same brightness.

Notice that the DC supply sits well below the AC peak value. It is called the r.m.s. value of the AC supply - but more of that later!



The symbols shown in the diagram are often used to distinguish between these forms of electrical power. We use both in this course.



- Both have ‘plug-top’ devices that plug into the AC mains electricity supply.
- The DC supply contains circuits which convert from AC power to DC.
- Some exercises, involving bulbs for example, can use either. Some can not. (The ‘energymeter’, for example, works only on DC.)
- Each worksheet layout suggests one type of power supply, but the flag shows whether there is an option:

AC supply



DC supply



Either



Conductors and Insulators

Materials which pass electricity are called **conductors**.

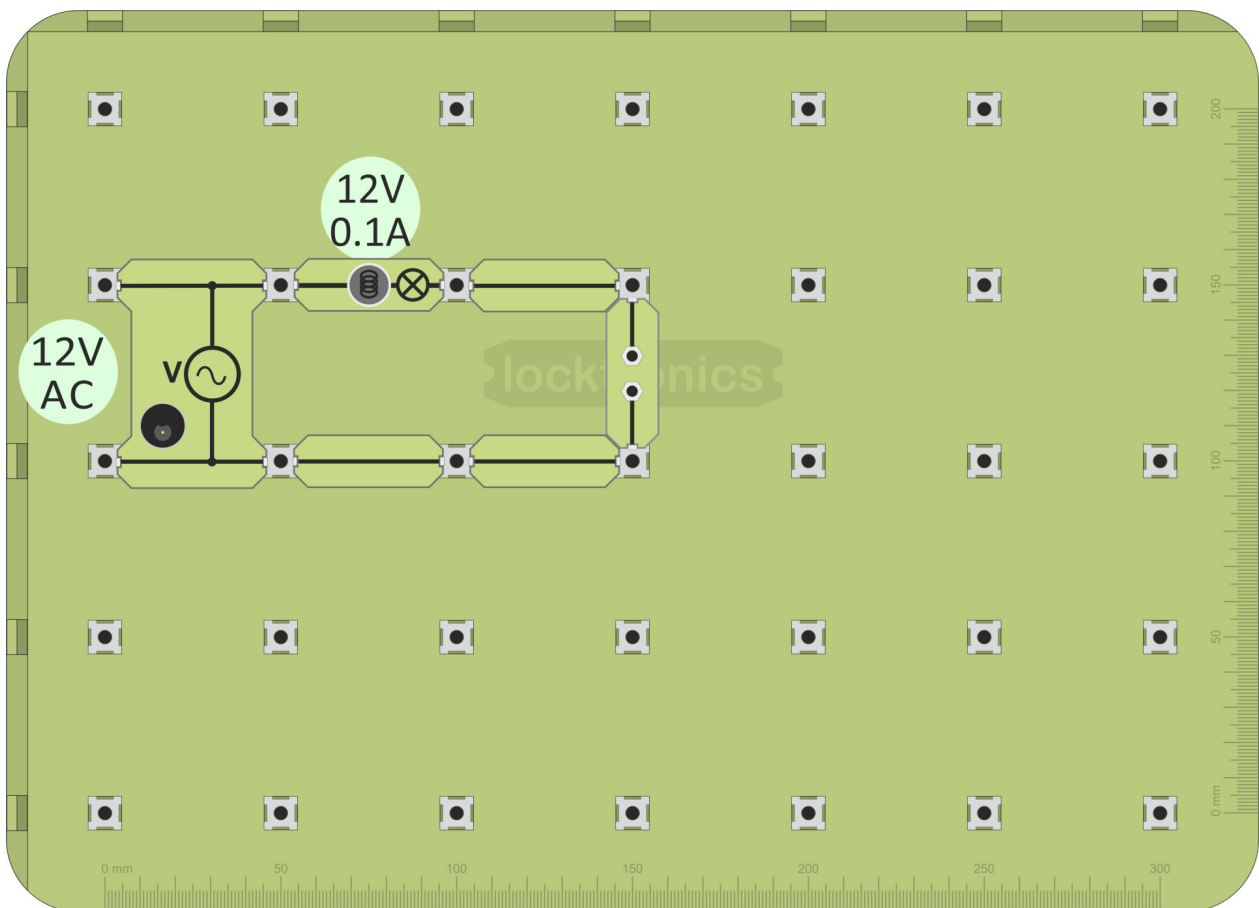
Materials which do not pass electricity are called **insulators**.

The hardware:



Universal component carrier

1. Build the layout shown below.
2. Connect the 12V power supply and switch on.

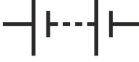


3. Put different materials across the gap in the universal component carrier. See if the bulb lights. (We are using the bulb as a simple continuity tester.) If it does, the material is a conductor; if not, it is an insulator (roughly speaking). Try some of the following: kitchen foil (aluminium), a rubber, paper, polythene, copper, air, lead, pencil lead (graphite), glass, wood, a coin, a piece of cloth, a plastic pen.
4. Fill in the table on the Student Handout with the findings from your experiment and try to answer the question.

Circuit Diagrams - 1

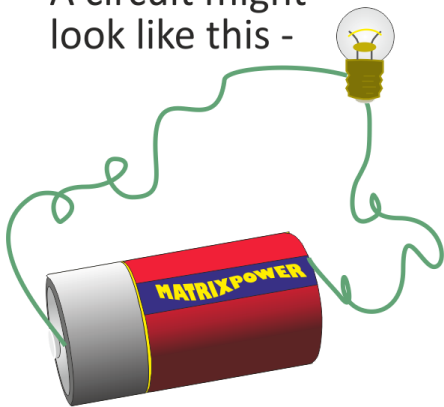
You have already been exposed to circuit symbols. The Locktronics carriers all show the conventional symbols for the components they carry.

Here is a summary of the ones used so far:

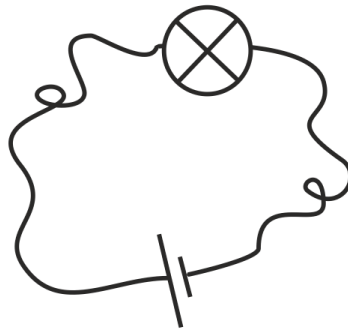
					
AC power supply	Battery or DC power supply	Toggle switch	Push switch	Lamp	Resistor

The aim is to clarify how a circuit is built, using an internationally recognised format.

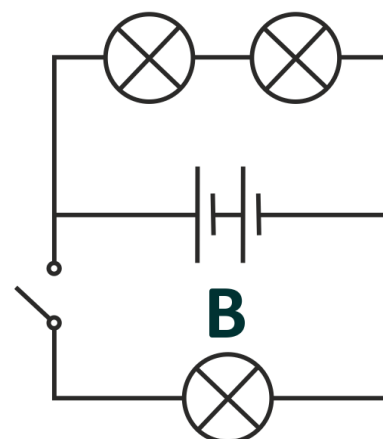
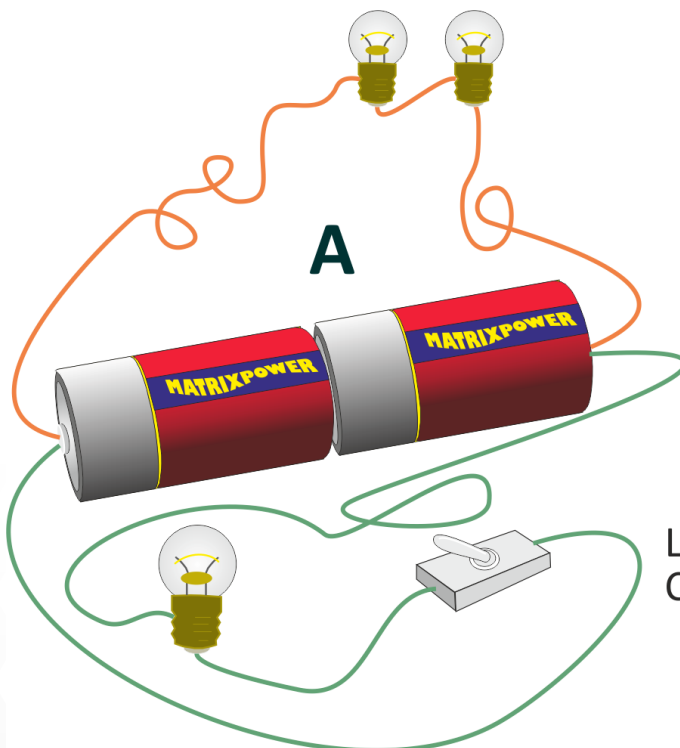
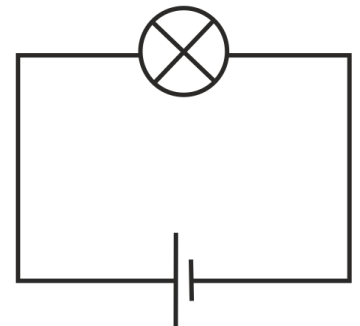
A circuit might look like this -



It is simpler to use symbols -



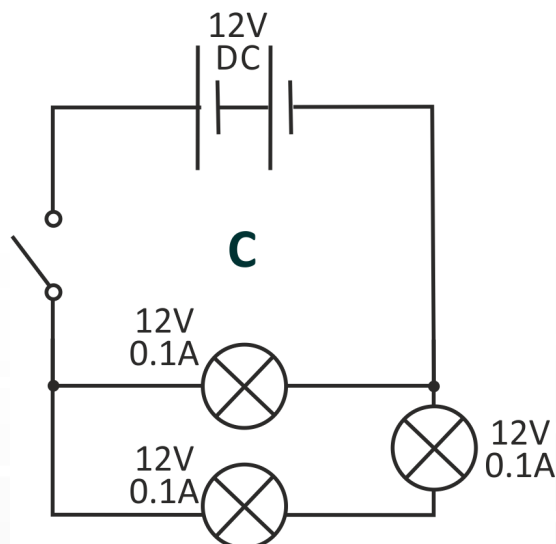
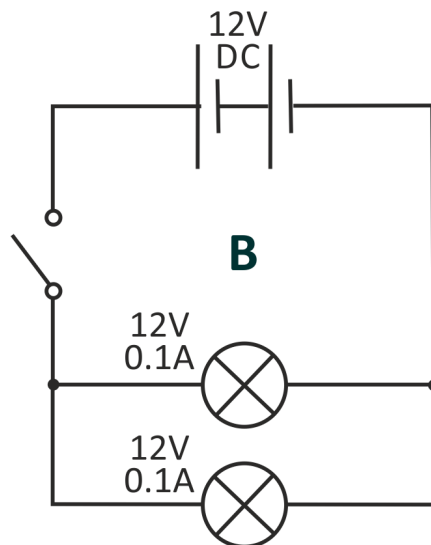
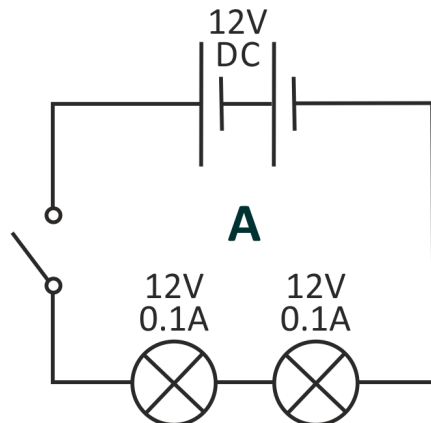
Or better still -



Look at the two circuits, **A** and **B**. Compare them. Are they the same?

Circuit Diagrams - 2

1. Build each of the three circuits, shown in circuit diagrams A, B and C, in turn. Each one uses a 12V DC power supply and 12V 0.1A bulbs.
2. Use the brightness of the bulbs to decide which circuit draws the biggest current from the power supply.
3. Record your decision in the Student Handout.



Current Path - 1

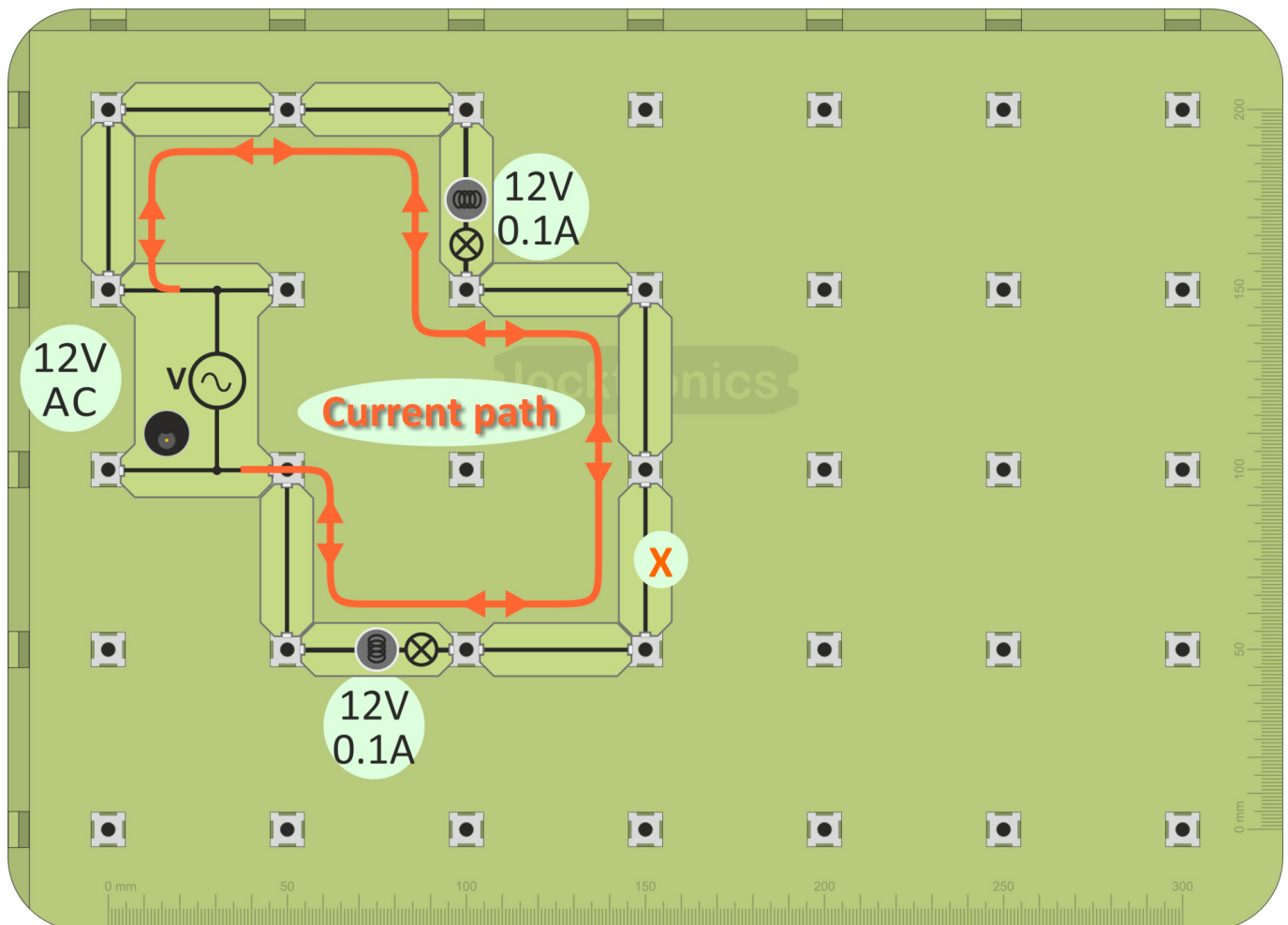
Power supply:

- Drives current around the circuit;
- Has two terminals (connection points) one 'positive' the other 'negative';
- Current flows from positive to negative.

Connecting links: Allow current to flow freely.

Circuit: Continuous length of conductor joining the power supply terminals .

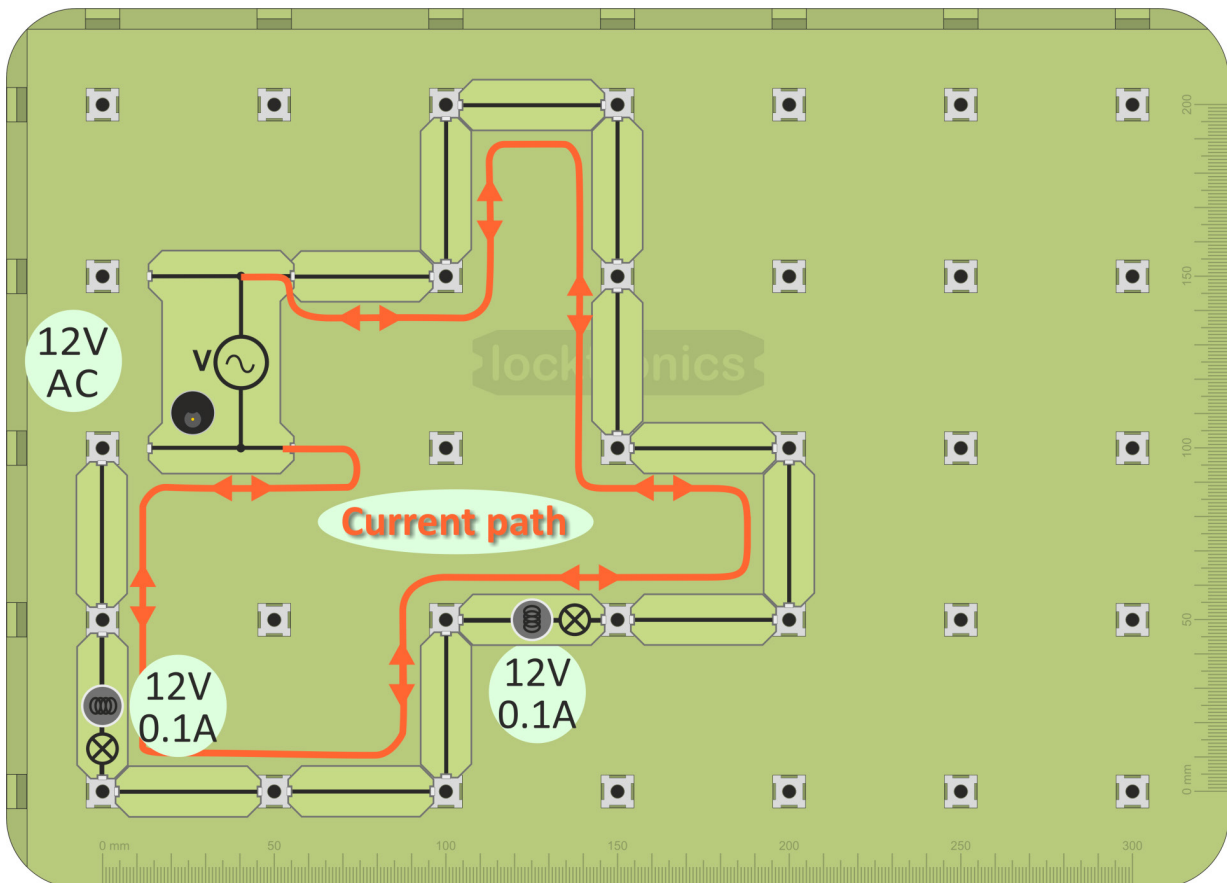
1. Build the layout shown below.
2. Connect the 12V power supply and switch on.



3. What happens if you remove a connecting link (for example 'X' - or any other)?
4. What happens if you unscrew one of the bulbs?

Current Path - 2

1. Build the layout shown below.
2. Connect the 12V power supply and switch on.



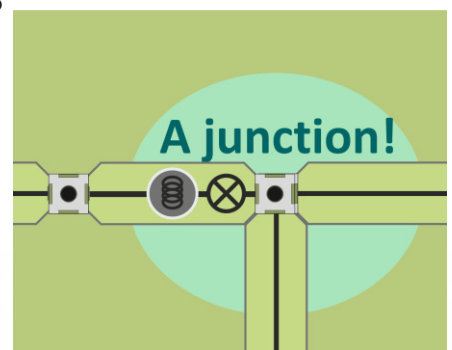
3. This layout has a different shape.

Does it make any difference to the way the circuit works?

Try other circuit shapes.

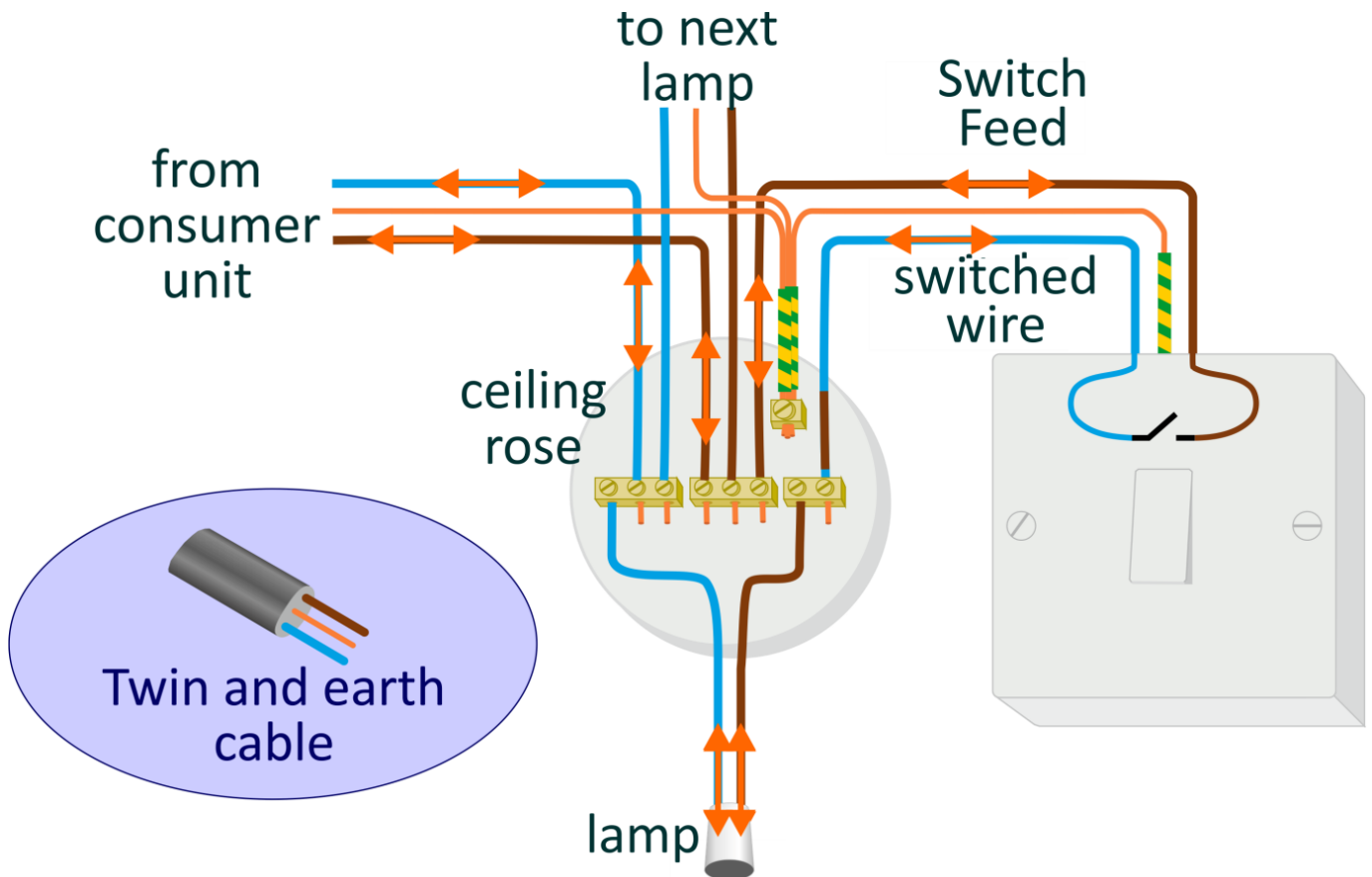
(Make sure that there are no 'branches' (junctions) in your circuits - these are covered later.)

Does the shape of the circuit make any difference to the way it works?



Current Path - 3

- When a fuse blows, it stops the current flowing to all devices, just like removing a connecting link.
- Turning off a switch has the same effect.



Domestic wiring is slightly different from the circuit you just built. It uses 'twin and earth' cable, containing a 'line', a 'neutral' and an 'earth' cable, bound together in a grey pvc sheath, for protection, rather than using separate single wires.

It is still connected in circuits allowing current to flow from one terminal of the power supply to the other.

The diagram shows how to wire up a pendant light to a ceiling rose and control it with a switch.

The orange arrows show the current path through this circuit.

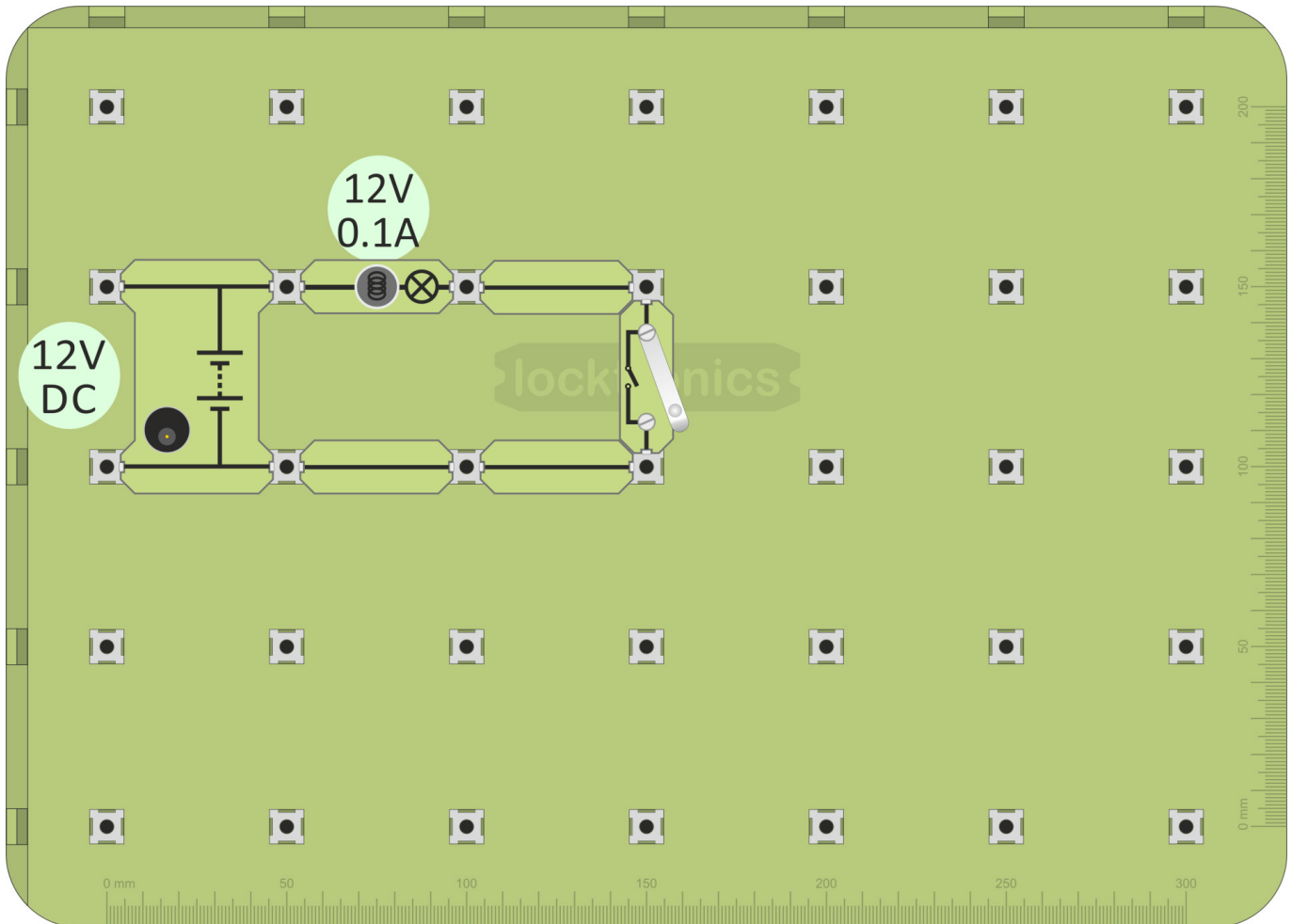
Trace it yourself to check that you understand it.

Follow it from the consumer unit:

- Through the switch,
- Through the lamp,
- Back to the consumer unit.

Effects of Electric Currents - 1

1. Build the layout shown below.
2. Connect the power supply, set to 12V, and switch on.



3. Close the switch. The lamp filament should be glowing yellow-hot.
4. Take hold of the glass envelope of the lamp. Does it feel warm?
5. Switch it off.
6. Clamp a few strands of wire wool between the posts of the universal component carrier, as shown in the diagram.
7. Remove the lamp holder from the circuit and replace it with the universal component carrier.
8. Close the switch and look at the wire wool strands. There should be a noticeable heating effect!

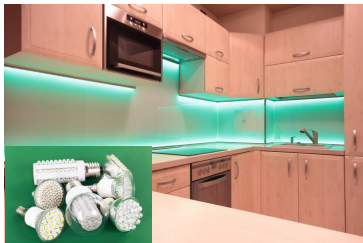


(Take care not to touch the component - it will be extremely hot!)

Heating Effects

When an electric current flows through a material, its energy is converted to heat.

You've seen a common example of the heating effect of a current - the filament lamp. The filament, the coil of wire at the centre of the glass 'bulb', usually made from the metal tungsten, is heated by the current to such a high temperature, over 2000°C , that it glows yellow-hot, giving out light.



Problem - they are very inefficient - typically only ~5% of the electrical energy appears as light. The drive is to higher efficiency lighting. One answer is LED (Light-Emitting Diode) lighting, which can be 10 times more efficient.

In the home, electricity supplies a host of other heating appliances, as the picture shows.



An unwanted and harmful aspect of electrical heating is found in short-circuits, where worn or damaged insulation lets wires touch, allowing very large currents and a lot of heat.

A solution is yet another application of electrical heating, the fuse - a short length of wire made from a metal with a low melting point. It acts as the weak point in the circuit. A large current flowing through it heats it so much that it melts. This breaks the circuit, stopping the current before it causes more widespread damage.

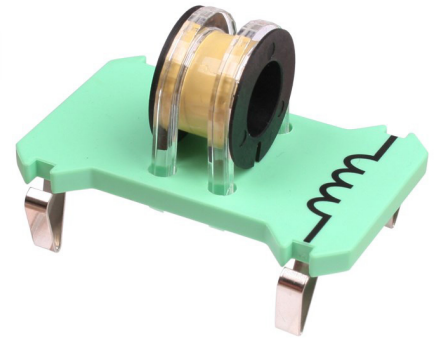


The reverse process takes place in a thermocouple. Two legs made from different metals are connected together. When the junction is heated, it generates a DC voltage. Thermocouples are used to measure temperature.

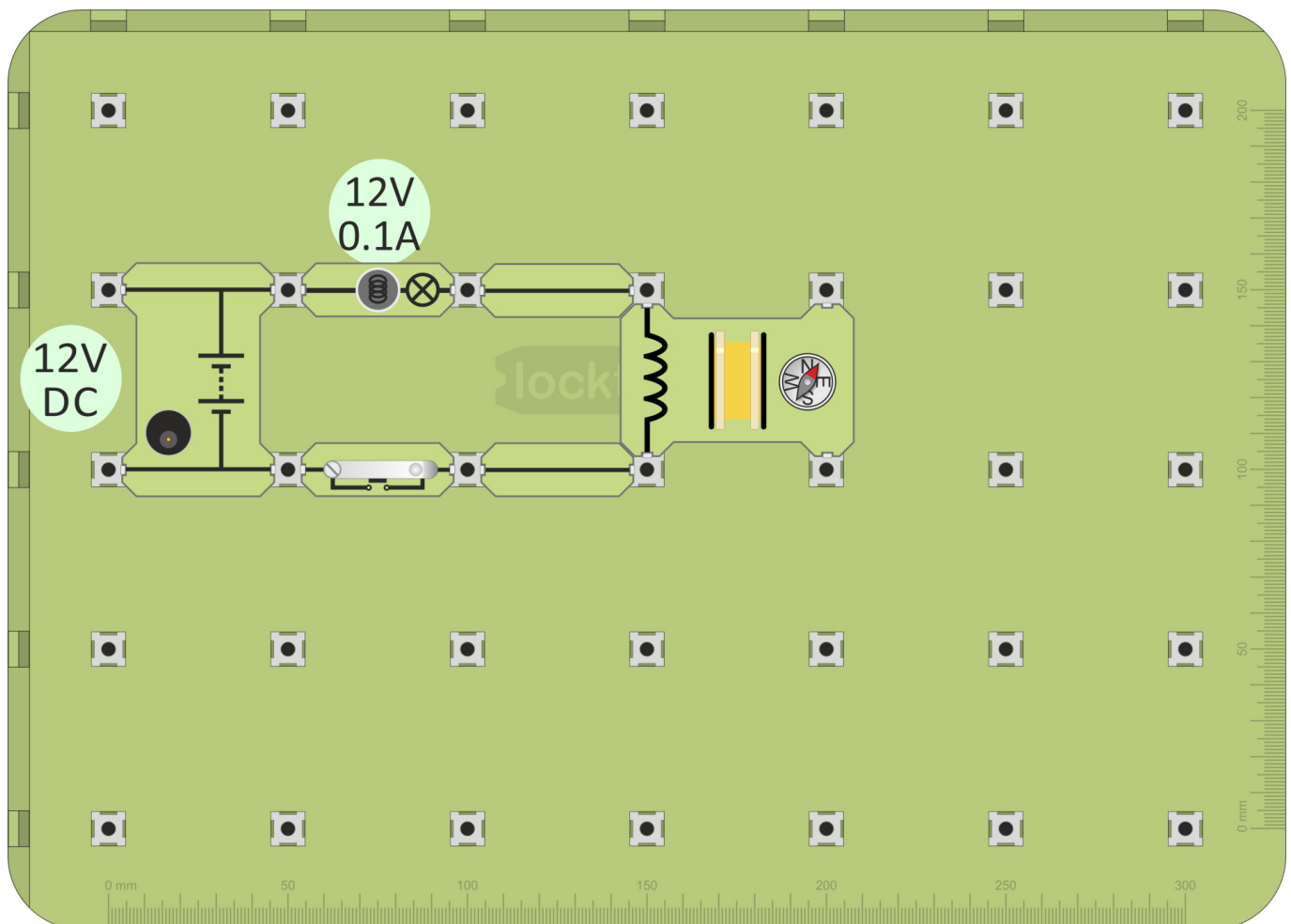
Effects of Electric Currents - 2

Effect 2 - Magnetic effect

The hardware - a 400 turn coil mounted on a carrier:



1. Build the layout shown below.
2. Connect the DC power supply, set to 12V, and switch on.

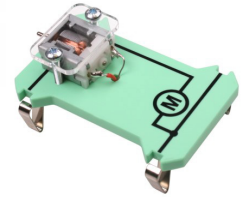


3. Place a magnetic compass next to the coil, as shown above.
4. Close the switch and watch the compass needle as you do so.
5. Now switch off and place a steel nail inside the coil.
6. Close the switch again, watching the needle as you do so. Is the effect stronger than before?
7. Wave a magnet near the compass to confirm what is happening.

Magnetics Effects

An electric current is ALWAYS accompanied by a magnetic field.

The principal application of the magnetic effect of electricity is the electric motor.



There are many examples of its use in the home.

(Some involve heating as well as magnetic effects.)



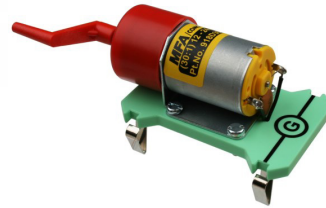
Other applications of electromagnetism include:

- Transformers - in power supplies, such as mobile phone chargers;
- Generators - used to power tools or as a stand-by in case of power cuts;
- Loudspeakers - in radios, televisions, computers and mobile phones;
- Circuit breakers - another protection against current overload and overheating.

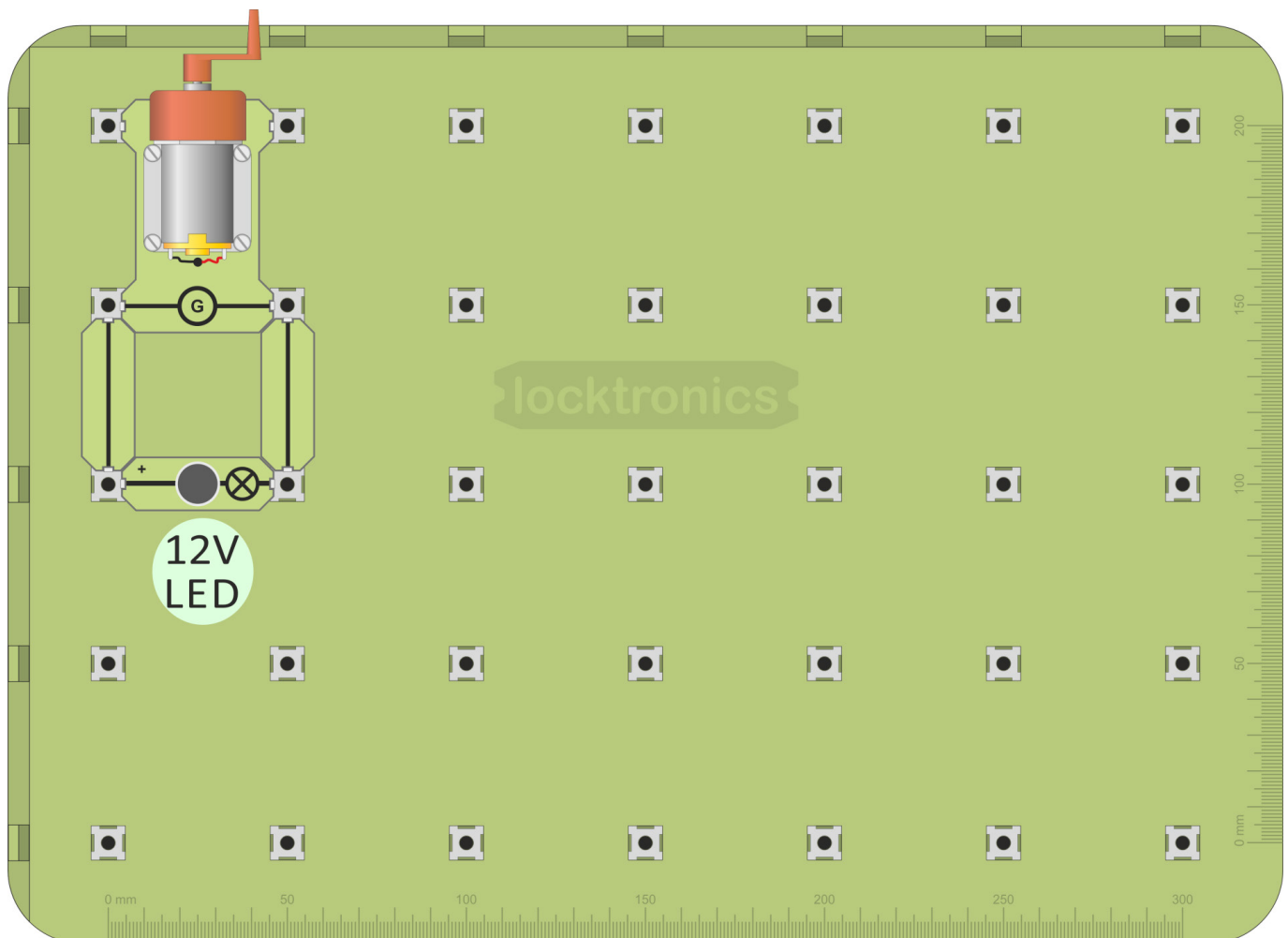


Generating Electricity

The hardware - a hand-cranked generator:



1. Build the layout shown below. Make sure that you use a 12V LED bulb carrier! (Look for the '+' sign at one end!)



2. GENTLY, turn the handle on the generator. The LED bulb should light. If it does not, turn the handle in the opposite direction. (The generator outputs DC. The current must flow in the right direction to make the LED light.)
3. Replace the LED carrier with a 12V 0.1A filament lamp. Turn the handle again.

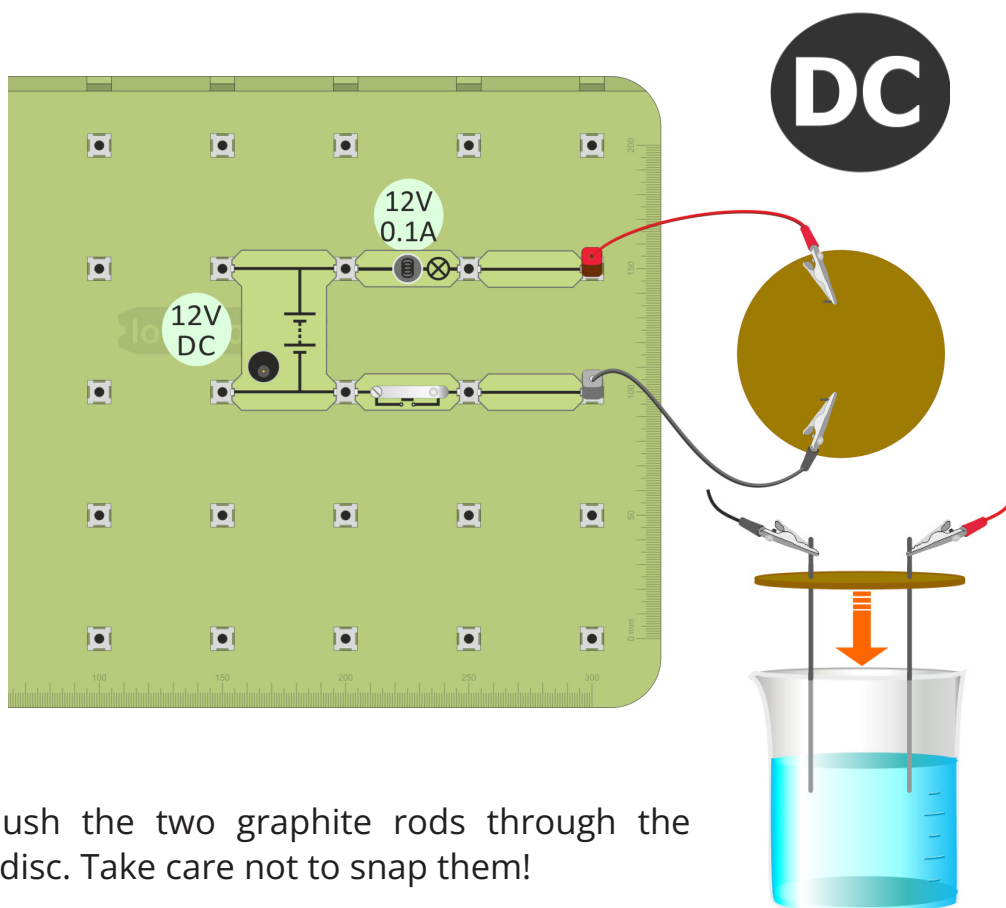
Which is easier to turn?

(This relates to the efficiency of the filament lamp, discussed earlier.)

Effects of Electric Currents - 3

Effect 3 - Chemical effect (Optional experiment)

1. Build the layout shown below. The lamp is included so that you can see when an electric current is flowing.
2. Connect the 12V DC supply and switch on.



3. Carefully push the two graphite rods through the hardboard disc. Take care not to snap them!

Now put on goggles to protect your eyes.

4. Pour about 200ml of the copper sulphate solution into a 250ml beaker. This concentration of copper sulphate is not hazardous, but make sure that you wash your hands at the end of the investigation.
5. Lower the rods into the beaker, so that the disc sits on top of the beaker.
6. Connect the rods to the rest of the circuit using crocodile clips.
7. Close the switch and watch carefully to see what is happening in the beaker. A chemical reaction is taking place, driven by the electric current.

Warning about copper sulphate solution:

Harmful if swallowed. Irritating to eyes and skin. Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

See CLEAPSS Hazard 27C for further details.

Chemical Effects

An electric current can create/be created by a chemical reaction.

An electric current is a flow of electrons, (which are tiny particles found in all atoms.)

A chemical reaction involves electrons transferring between atoms. No wonder electric currents and chemical changes are related!

The most obvious example of this link is the battery. In 'dry' batteries, a chemical reaction generates a voltage which can drive an electric current.

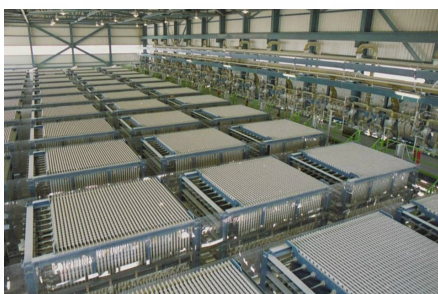
In rechargeable batteries, this process can be reversed - a current flowing the 'wrong' way can reverse the chemical reaction, storing up energy for later use.



Another example is the technique known as electroplating. In this, an electric current flowing through a chemical solution deposits a metal on one of the electrodes.

This may be done:

- For protection - objects made from iron can be protected from corrosion by plating them with zinc (galvanising);
- For decoration - objects made from a cheaper metal can be plated with a more expensive one such as gold or silver.



Electrolysis is a related technique.

Here, the electric current is used to extract or purify chemicals such as chlorine and copper.

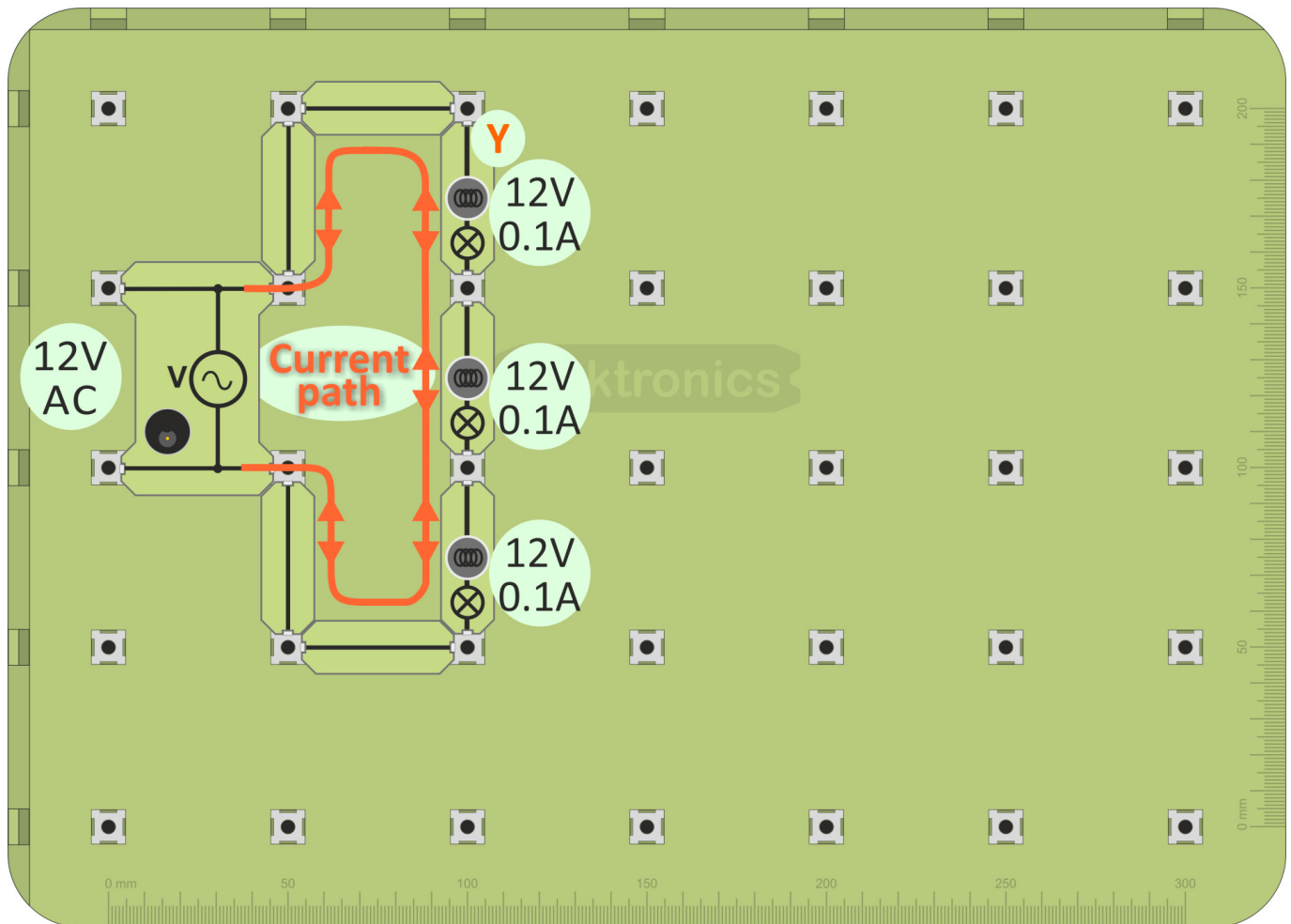
Connect in Series - 1

Series:

- Devices connected one after the other in a line;
- No alternative routes, no branching;
- Only one path for the current through the connection.

Remember! - the brighter the bulb, the bigger the current!

1. Build the layout shown below. This is a series circuit - the lamps are connected in a line with no junctions.
2. Connect the 12V power supply and switch on.



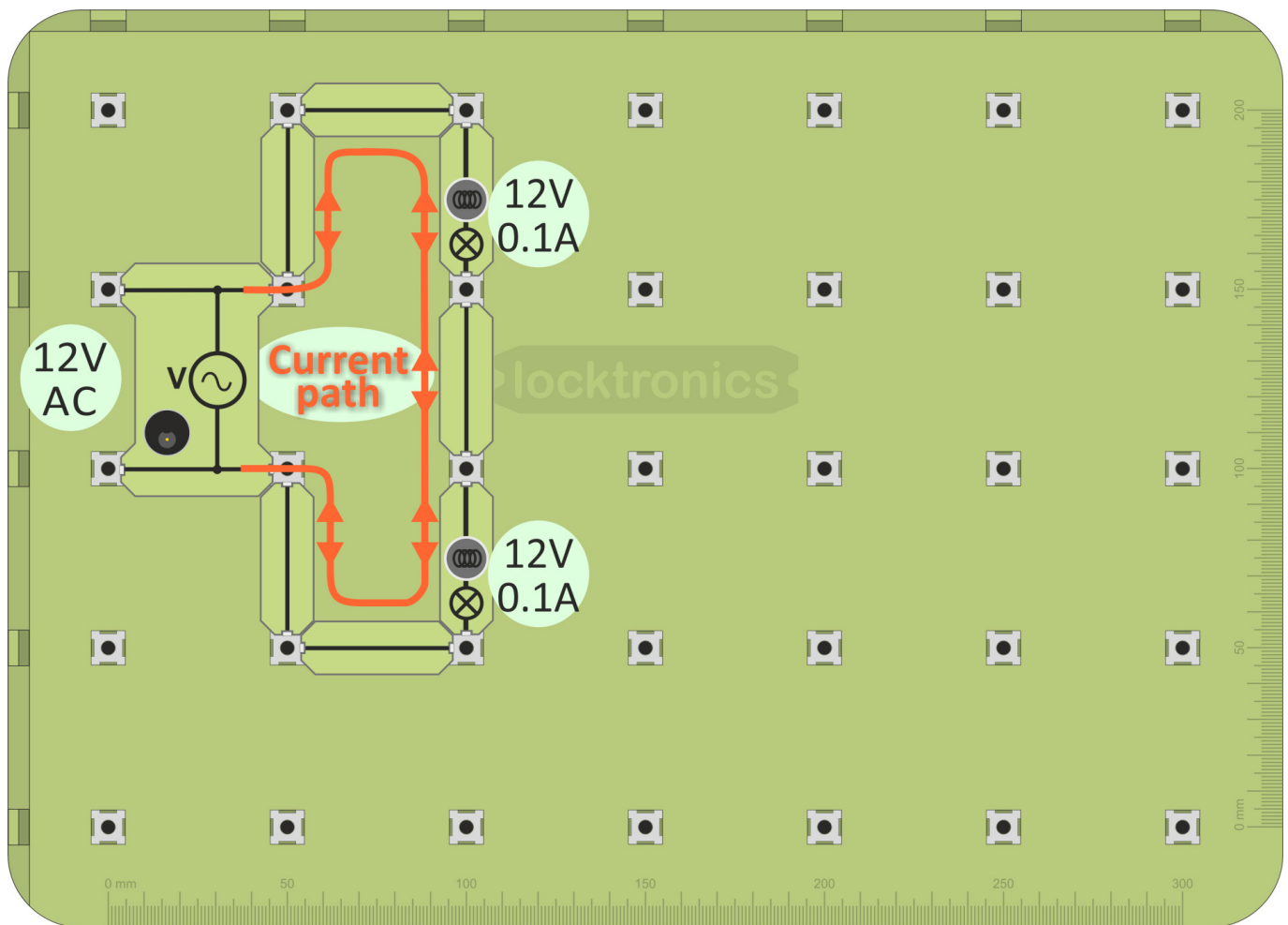
3. What do you notice about the brightness of the three lamps?
4. What happens if you unscrew one of the bulbs (bulb 'Y' for example)?
5. Write your findings in the Student Handout.

**If the lamps are of different brightness, look at
MES bulbs
and then come back to the next worksheet!**

Connect in Series - 2

Remember! - the brighter the bulb, the bigger the current!

1. Build the layout shown below. This is also a series circuit but this time there are only two lamps.
2. Connect the 12V power supply and switch on.



3. What do you notice about the brightness of the two lamps?
4. How does it compare with brightness of the lamps in the previous circuit?
5. What does this show about the current flowing in the circuit?
6. Unscrew one of the bulbs. Does this have the same effect as in the previous circuit?
7. Write your findings in the Student Handout.

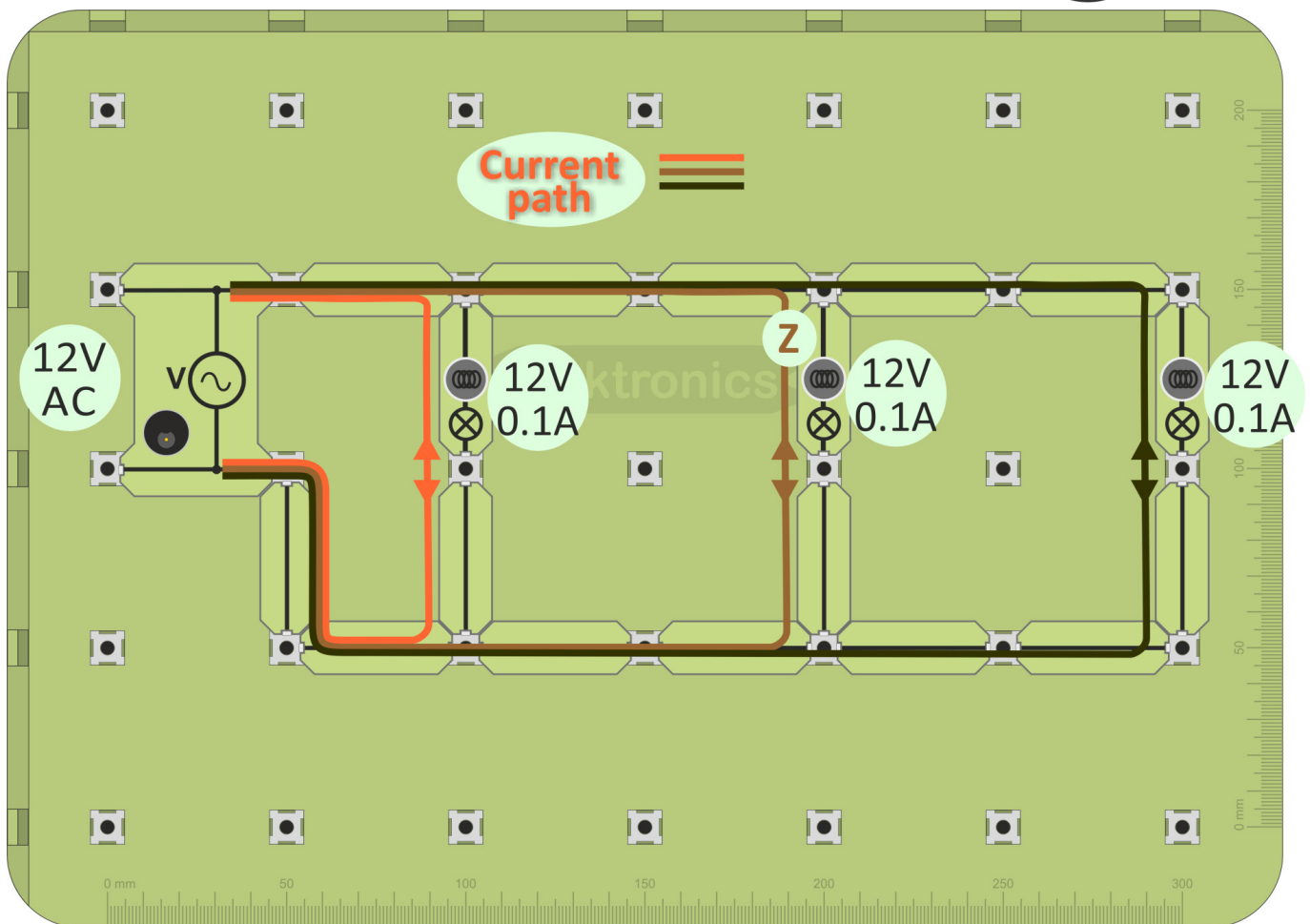
**If the lamps are of different brightness, look at
MES bulbs
and then come back to the next worksheet!**

Connect in Parallel

Parallel:

- Devices have their own separate 'branch-line';
 - Ends of a device connect to corresponding ends of all other devices;
 - Each device has its own path for the current through the connection.
1. Build the layout shown below. This is a parallel circuit - each lamp is connected in its own 'branch-line'.
 2. Connect the 12V power supply and switch on.

AC
DC



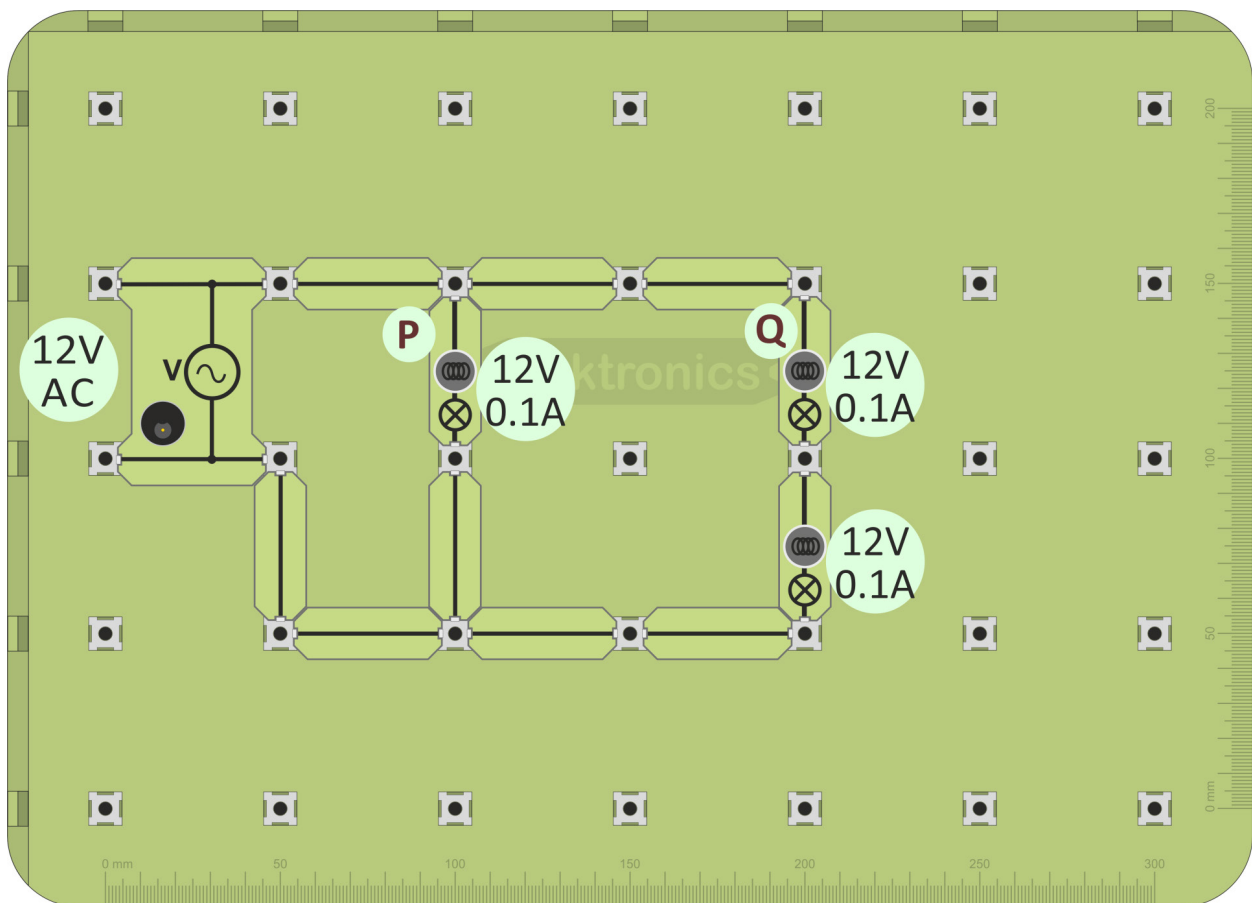
3. What do you notice about the brightness of the three lamps?
4. What happens if you unscrew one of the bulbs (bulb 'Z' for example)?
5. Notice how the current path differs from that for the series circuit!
6. Answer the questions in the Student Handout.

If the lamps are of different brightness, look at
MES bulbs
and then come back to the next worksheet!

Series/Parallel - 1

Often, some parts of a circuit are connected in series while other parts are in parallel. The rules you have observed in the previous circuits still apply.

1. Build the layout shown below. Which bulbs are in series and which in parallel? (Try to picture the current paths through the bulbs!)
2. Connect the 12V power supply and switch on.

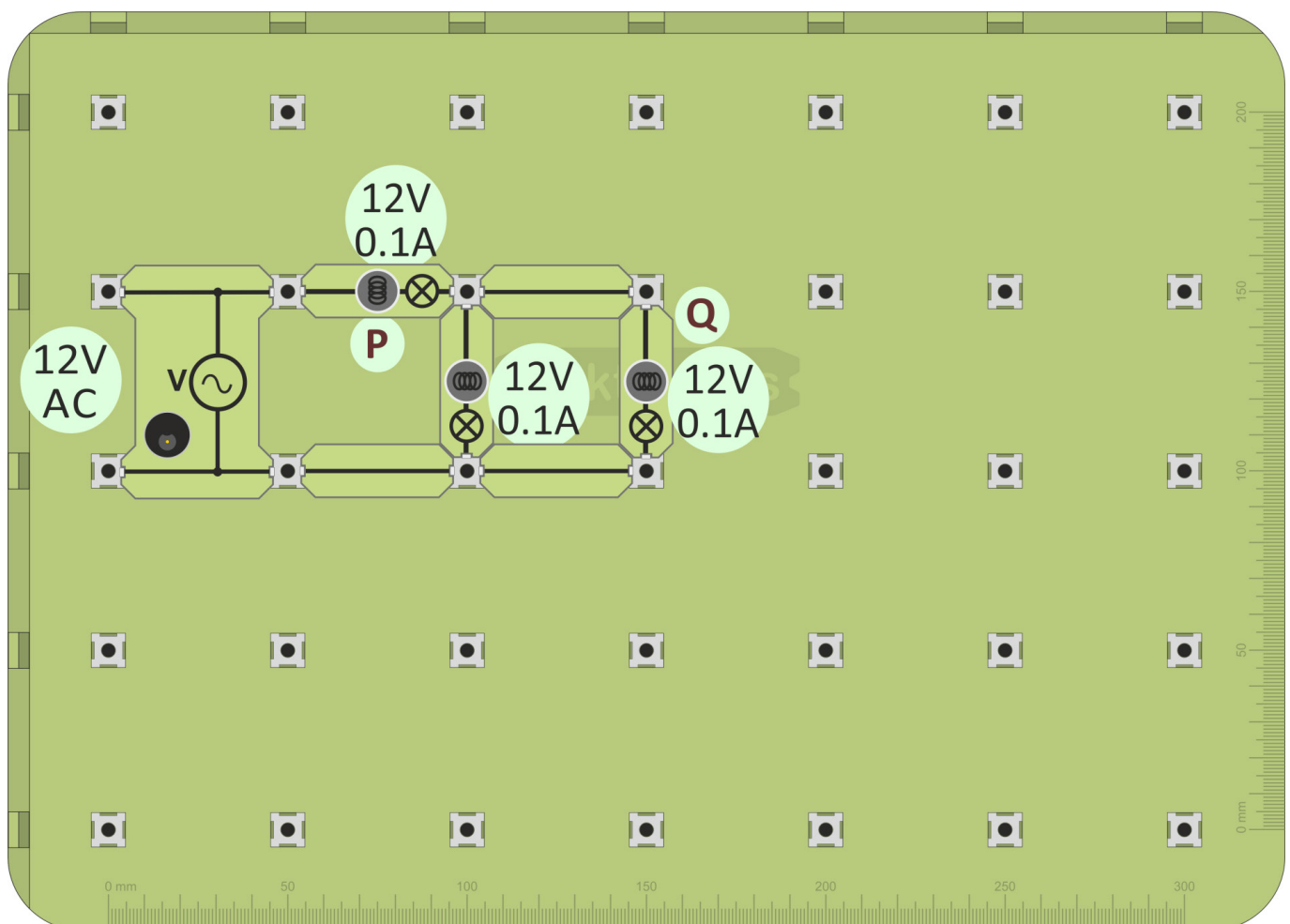


3. What do you notice about the brightness of the three lamps now?
4. What happens if you unscrew:
 - Bulb 'P';
 - Bulb 'Q'?
5. Can you explain these differences?
6. Answer the questions in the Student Handout.

Series/Parallel - 2

Here is another circuit with a mixture of series and parallel connections.

- Decide where the series and parallel connections are. (Once again, picture the current paths!)
 - Predict which bulb will be the brightest and then check to see if you were right!
1. Build the layout shown below.
 2. Connect the 12V power supply and switch on.



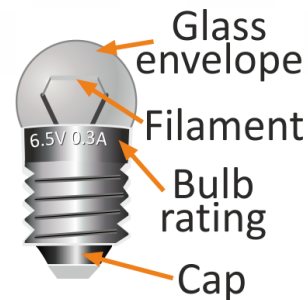
3. Compare the brightness of the three lamps? Were you right?
4. What happens if you unscrew:
 - Bulb 'P';
 - Bulb 'Q' ?
5. Can you explain these differences?
6. Answer the questions in the Student Handout.

MES Bulbs

- MES bulbs are mass-produced to reduce cost.
- As a result, they are not quite identical:

They may have:

- Different filament lengths;
- Different filament diameters;
- Different heat losses.



Given identical conditions, they will not give the same brightness.

You've been directed to this worksheet because the lamps in your circuit are not the same brightness.

There are two possible reasons for this:

- The bulbs are not quite identical;
- Different currents flow through them.

Try the following test:

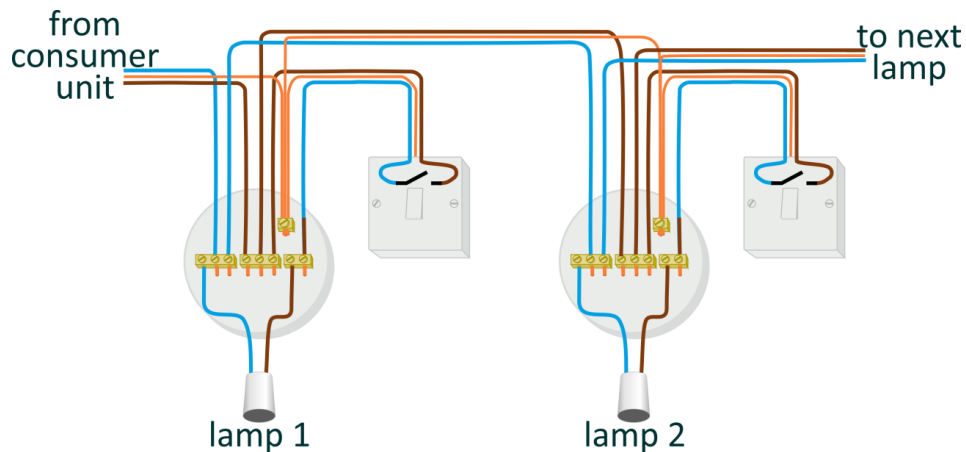
- Swap the lamps round.
- If the pattern of brightness is the same as before, then the currents are different.
- If the brightest bulb is still the brightest, then the bulbs are different.

What does your test show?

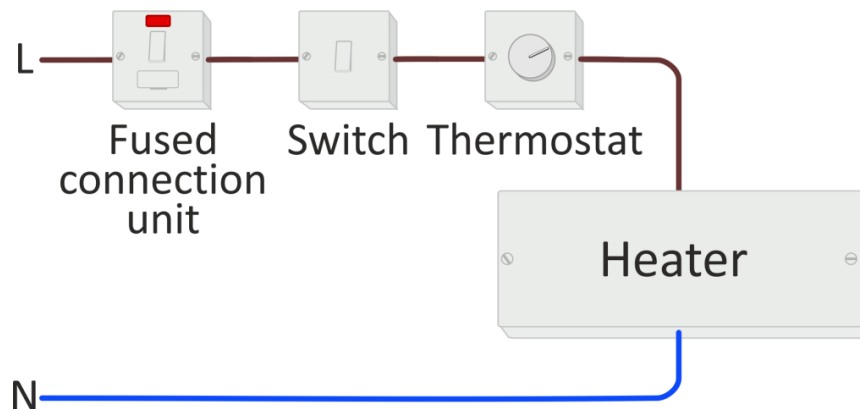
Series/Parallel Applications

In domestic lighting, it is important that lamps operate independently especially when one bulb 'blows'.

Hence they are connected in parallel, as the diagram shows.



Controls, like fuses, switches and thermostats, must be able to 'break' the circuit and stop current flow to the load device, such as a heater. As a result, they are connected in series with the load.

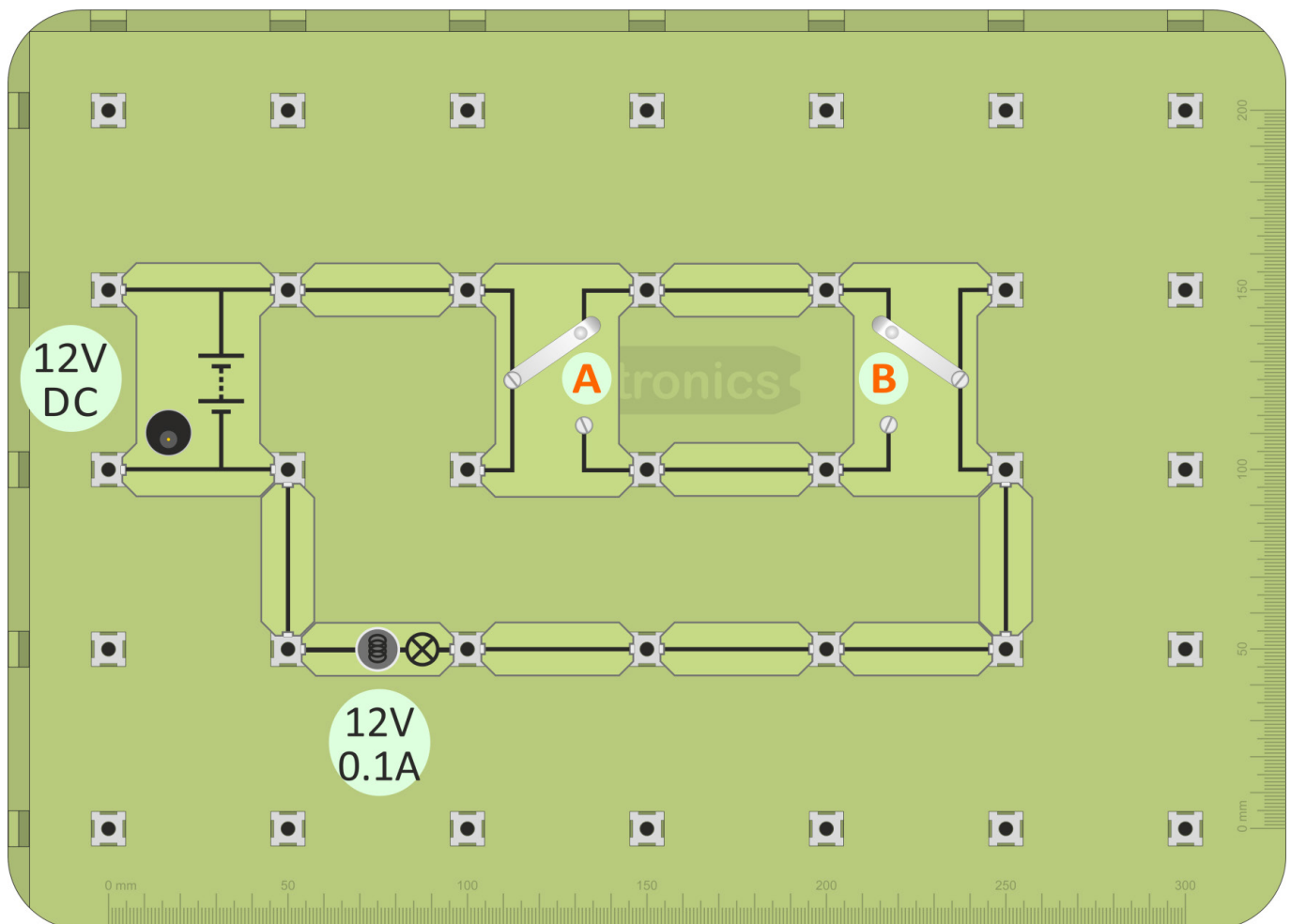


Staircase Circuit - 1

Here is another common circuit - a two-way switching circuit used to operate a light using either switch **A** or switch **B**. The light may be at the top of a staircase, with one switch at the bottom of the stairs and the other at the top.

It uses two changeover switches for **A** and **B**. These are sometimes called 'single-pole-double throw' or SPDT switches.

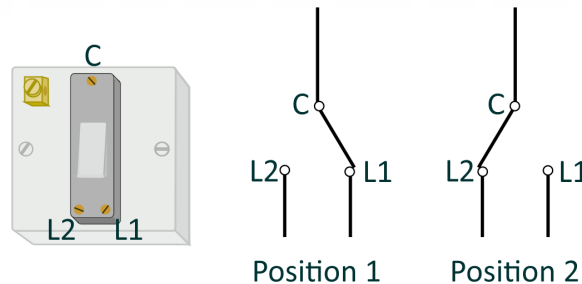
1. Build the layout shown below, using two 'changeover' switches, 'A' and 'B'.
2. Connect the 12V power supply and switch on.



3. Move switch **A** into the other position. What happens?
4. Now move switch **B** into the other position. What happens?
5. For both of these, trace out the current paths.
6. Complete the diagram in the Student Handout by adding the current path for the arrangement shown there.

Staircase Circuit - 2

In practice, the circuit uses two changeover switches like the one shown:

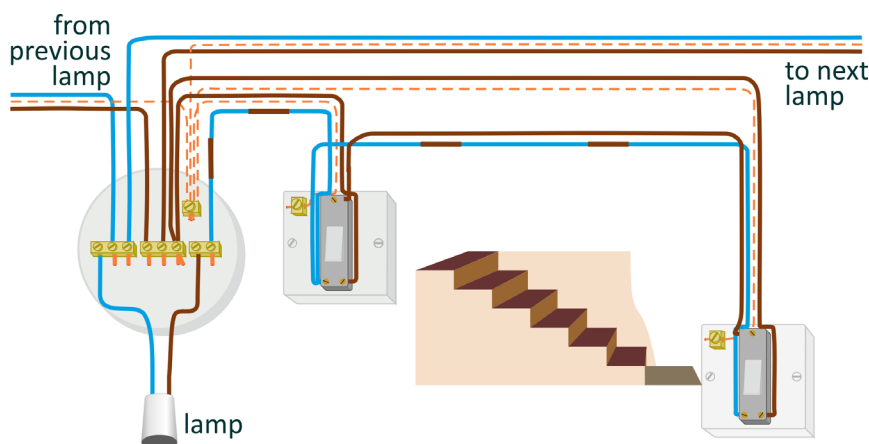


It has three terminals, labelled **C** (for Common), **L1** and **L2**.

Operating the switch connects **C** to either **L1** or **L2**, as shown above.

The two-way switching circuit is shown below.

The earthing connections are shown as dotted lines to make the circuit clearer.



Notice that:

- The **L1** terminals are connected together;
- The **L2** terminals are connected together and to the switched wire to the lamp;
- The **C** terminals are connected together.

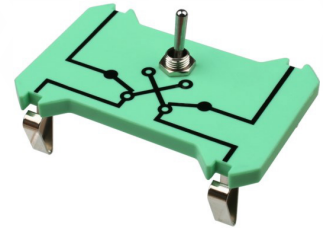
Starting with the incoming 'live' connection (brown) from the previous lamp, trace out the circuit.

- With the left-hand switch is in position 1, **L1** is connected to **C**, making it 'live';
- The **C** terminal in the other switch is connected to it, and so is also 'live';
- With the right-hand switch is in position 2, **L2** is connected to **C** and so is 'live';
- This makes the brown wire to the lamp 'live' and so the lamp lights.

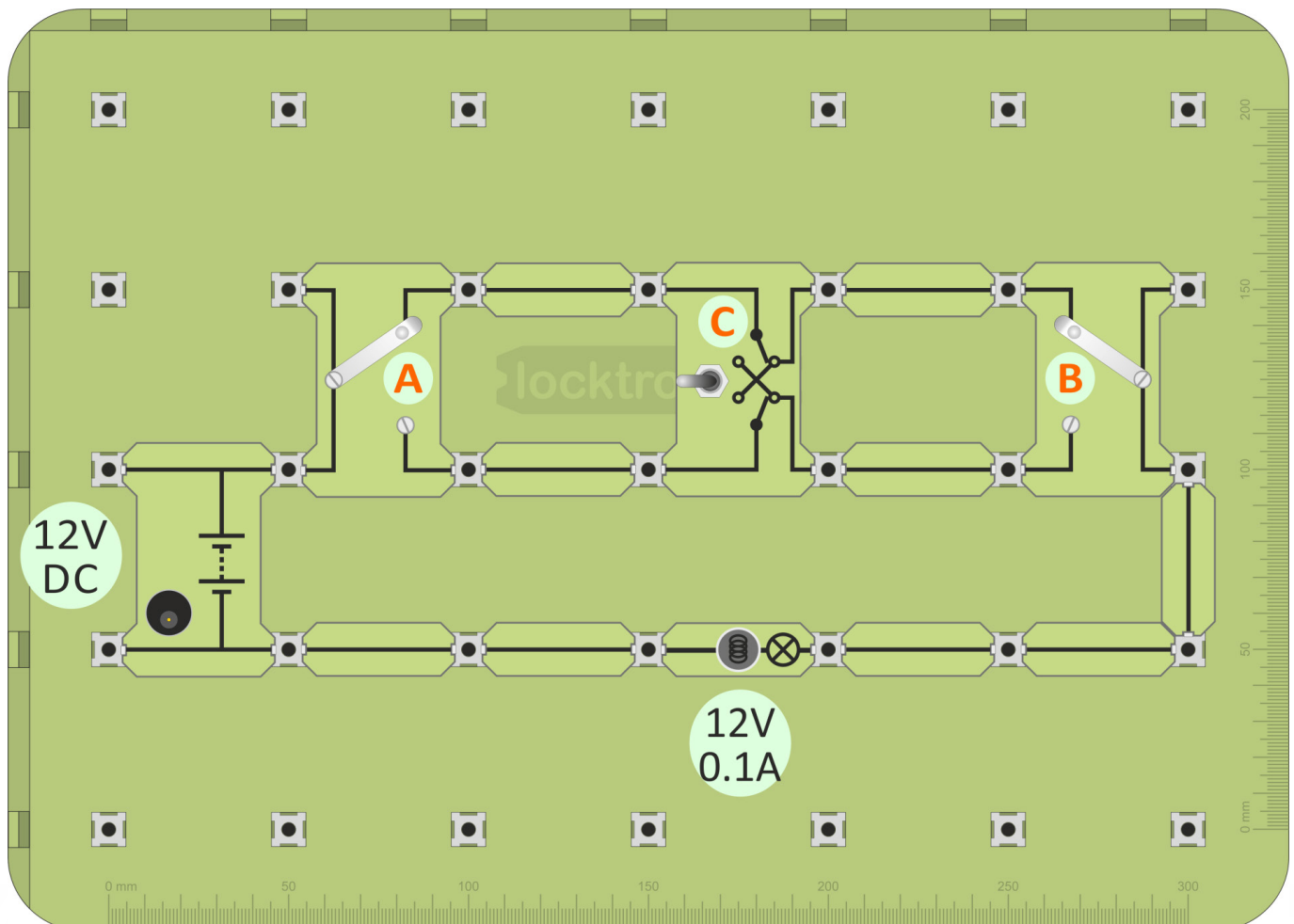
In the same way, trace out the circuit when the switches are in the other positions.

3-Way Control - 1

This is a modification of the previous circuit. By adding a third switch - an intermediate switch, (also called a reversing or a double-pole-double-throw (DPDT) switch,) the lamp can be controlled by three switches, **A** or **B** or **C**.

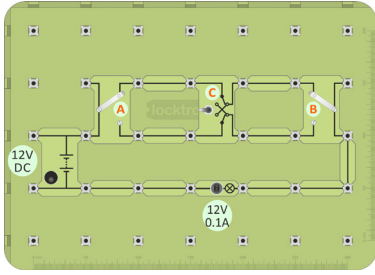


1. Build the layout shown below, using two 'changeover' switches, 'A' and 'B' and an intermediate switch 'C' (or modify the previous circuit by adding 'C' .)
2. Connect the 12V power supply and switch on.

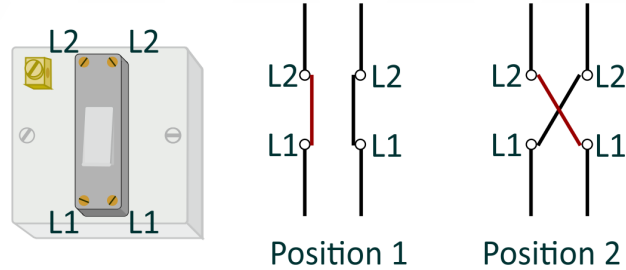


3. Check that the lamp can be controlled by all the switches.
4. For all eight combinations of switch positions, trace out the current paths.
5. Complete the diagram in the Student Handout by adding the current path for the arrangement shown there.

3-Way Control - 2



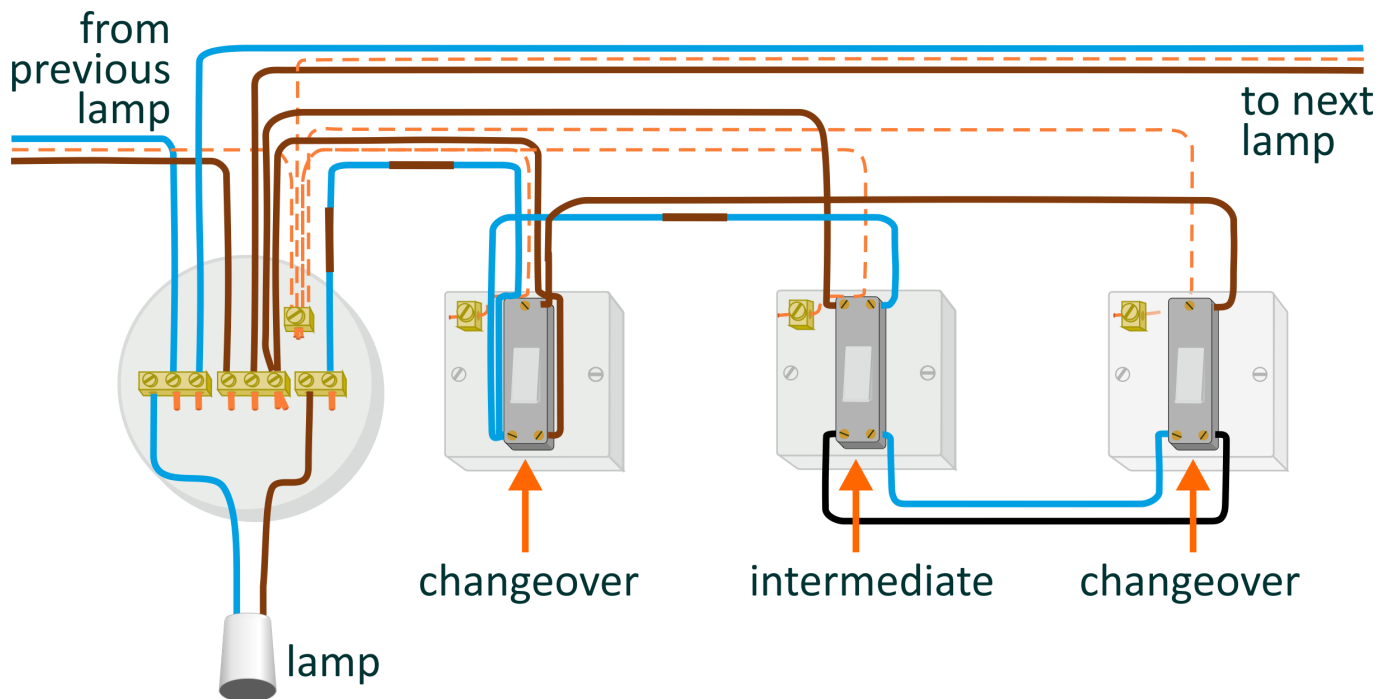
Now, a third switch, an intermediate switch, is added:



It has four terminals, two labelled **L1** and two labelled **L2**.

Operating it makes the connections shown above.

The three-way switching circuit is shown below.



Compare this circuit with the one you just built using 'Locktronics'.

Measuring Voltage - 1



The picture shows one form of multimeter. It has a wide range of uses - varies from model to model - but usually includes measuring AC and DC voltage and current.

When using a multimeter, before you switch it on:

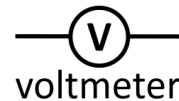
- Take care to plug the probes into the correct sockets;
- Select the correct range.

(‘Auto-ranging’ versions select the best range automatically.)

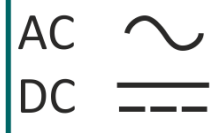
Voltage:

- Is a measure of the force pushing the electrons around the circuit;
- Measures energy lost or gained as an electron moves through part of a circuit
- Is measured with a voltmeter connected in parallel with the component.

The circuit symbol for a voltmeter is shown in the diagram.



Using a multimeter to measure voltage:



Multimeters can measure both AC and DC.

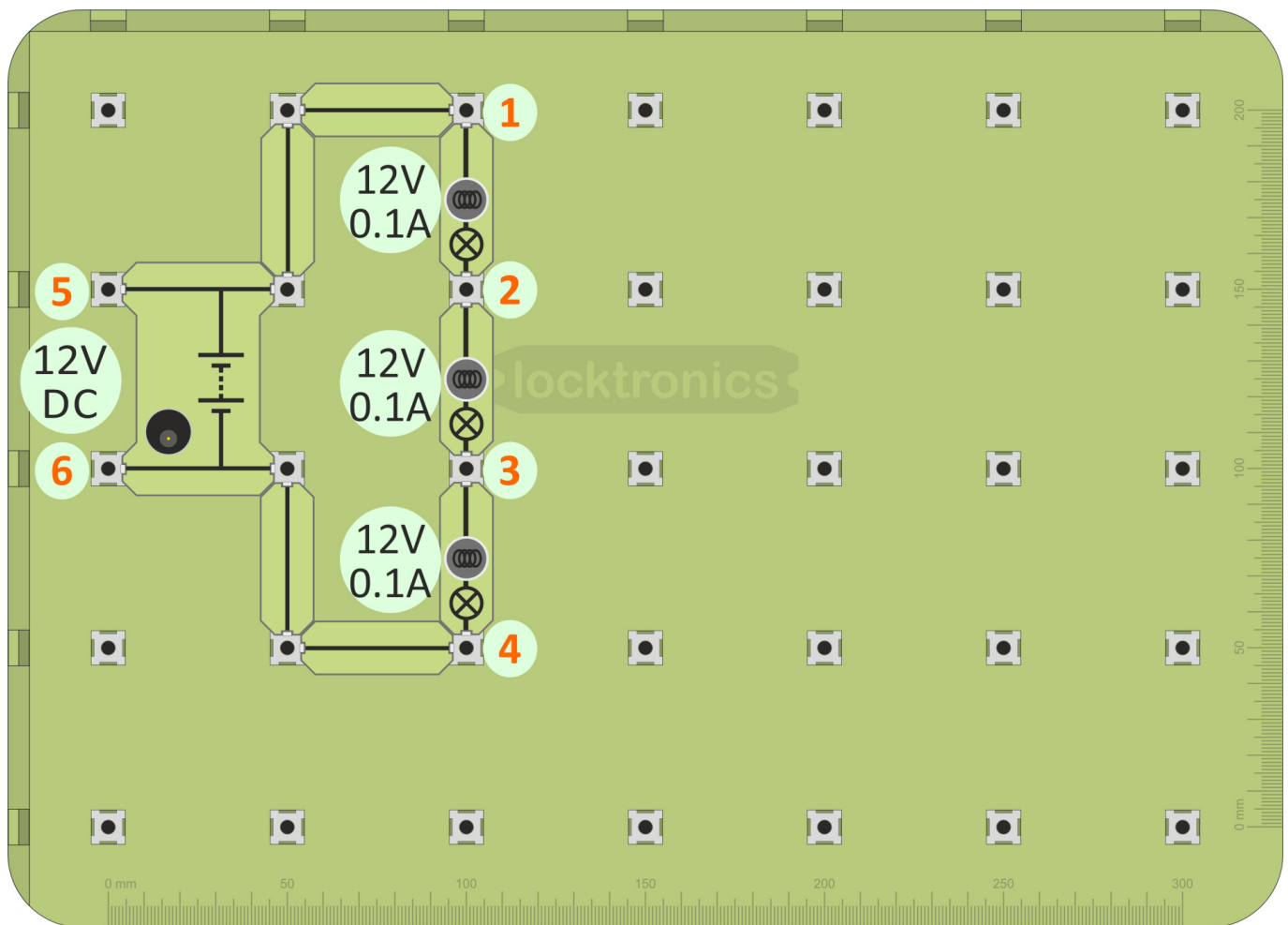
The following symbols distinguish between them:

- Plug one wire into the black ‘COM’ socket.
- Plug another into the red ‘V’ socket.
- Select the 20V DC range by turning the dial to the ‘20’ mark next to the ‘V’ symbol. (It is good practice to set the meter on a range that is much higher than the reading you are expecting. Then refine it by choosing a lower range to suit the voltage you find.)
- Plug the wires into the sockets at the ends of the component under investigation.
- Switch on the multimeter when you are ready to take a reading.
- A ‘-’ sign in front of the reading means that the meter wires are connected the wrong way round. Swap them over to get rid of it!



Measuring Voltage - 2

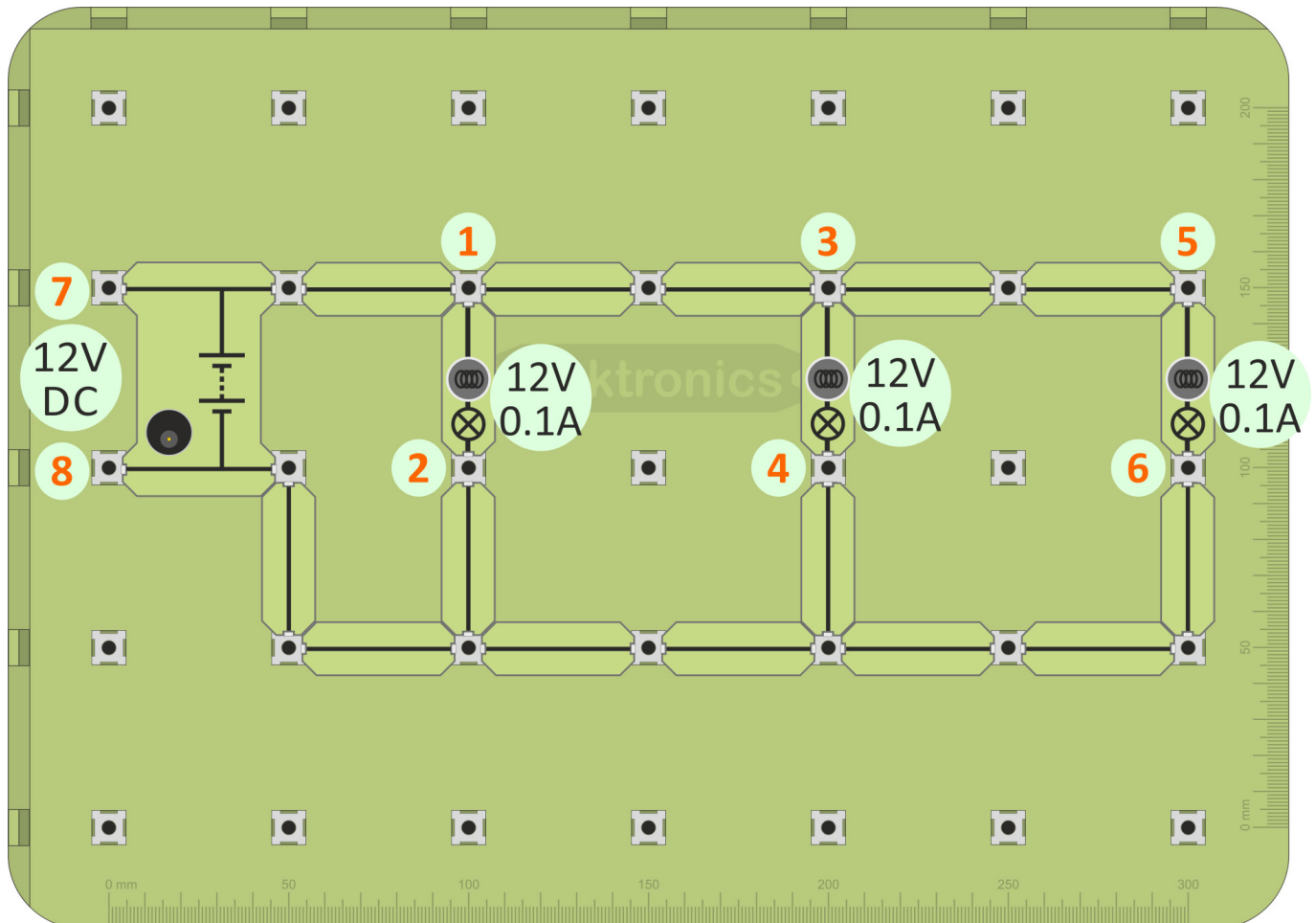
1. Build the layout shown below - a series circuit with only one route around it.
2. Connect the power supply, set to 12V, and switch on.



3. Set up the multimeter to read voltages up to 20V DC - see the previous page.
4. Measure the voltage across the top bulb, by plugging the multimeter leads into posts '1' and '2'.
5. Next, measure the voltage across the middle bulb, using posts '2' and '3'.
6. Then measure the voltage across the third bulb, using posts '3' and '4'.
7. Finally, measure the supply voltage, using posts '5' and '6'.
8. Add together the voltages across the three bulbs and compare it with the supply voltage. What do you notice?
9. Enter all your results into the table in the Student Handout and answer the question.

Measuring Voltage - 3

1. Build the layout shown below - this time a parallel circuit.
2. Connect the power supply, set to 12V, and switch on.

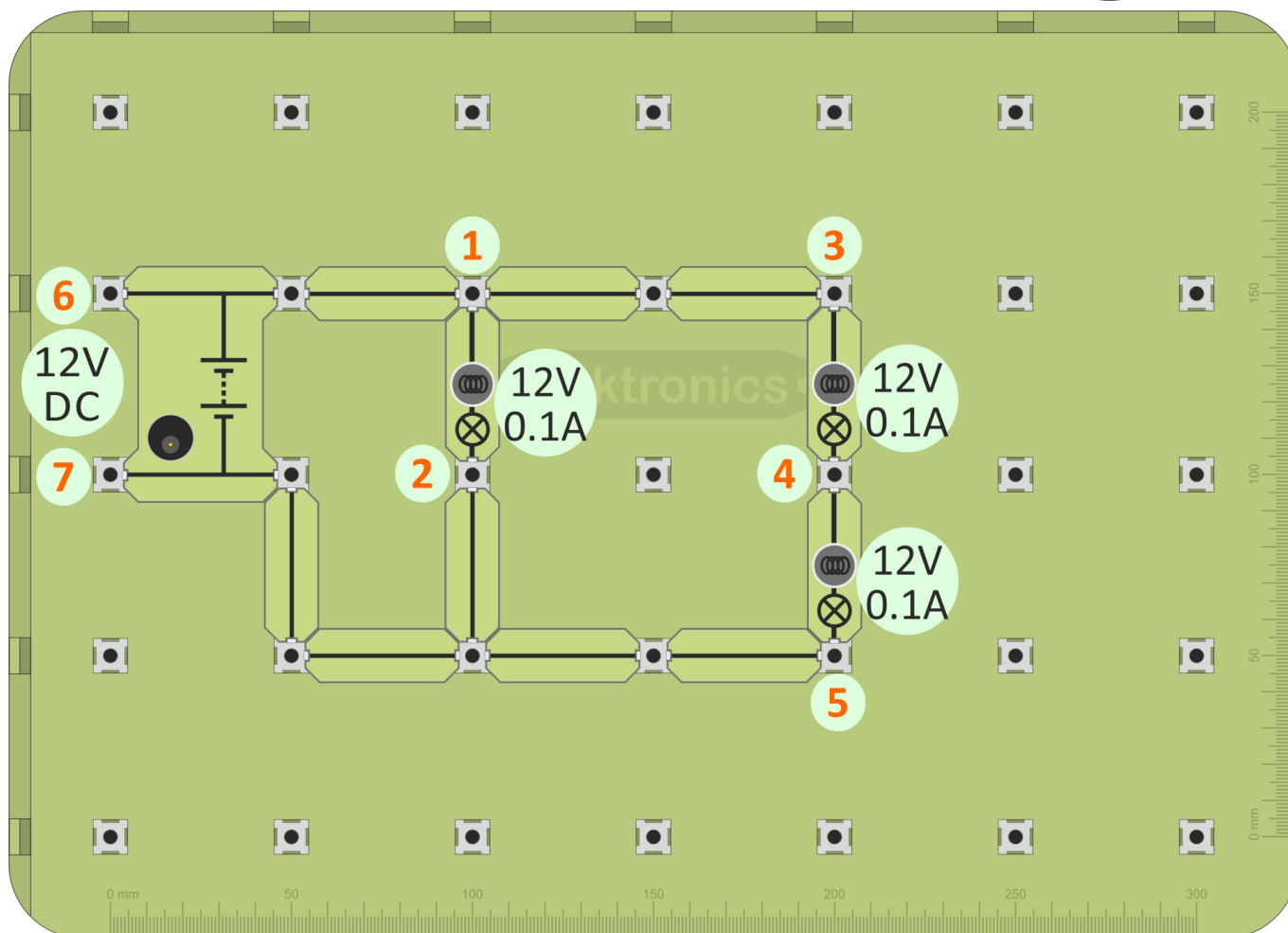


3. Set up the multimeter to read voltages up to 20V DC.
4. Measure the voltage across the first bulb, by plugging the multimeter leads into posts '1' and '2'.
5. Next, measure the voltage across the middle bulb, using posts '3' and '4'.
6. Then measure the voltage across the third bulb, using posts '5' and '6'.
7. Finally, measure the supply voltage, using posts '7' and '8'.
8. Look at the voltages across the three bulbs and across the supply voltage. What do you notice?
9. Enter all your results into the table in the Student Handout and answer the question.

Measuring Voltage - 4

Now we return to one of the circuits that have both series and parallel connections to see why the bulbs have the brightness we observed earlier.

1. Build the layout shown below and switch on the power supply.



2. Measure the voltage across the first bulb, using posts '1' and '2'.
3. Next, measure the voltages across the other two bulbs, using posts '3' and '4' and then '4' and '5'.
4. Finally, measure the supply voltage, using posts '6' and '7'.
5. Look at the voltages across the bulbs. Does this explain the different brightness?
6. What do you notice about the supply voltage and the voltages across the bulbs?
7. Enter all your results into the table in the Student Handout and answer the question.

Investigate the other mixed circuit which you built earlier.

Measuring Current - 1



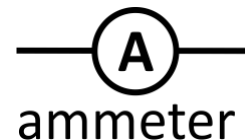
When using a multimeter to measure current, plug the probes into the 'A' and 'COM' sockets, or equivalents.

Then select the correct range, either from the 'A~' section, for AC current or the 'A' section, for DC current.

Finally, switch on.

Current:

- Measures the number of electrons passing any point in the circuit each second;
- Measures the rate of flow of electrical charge in the circuit;
- Is measured with an ammeter connected in series with the component. The circuit symbol for a ammeter is shown in the diagram.

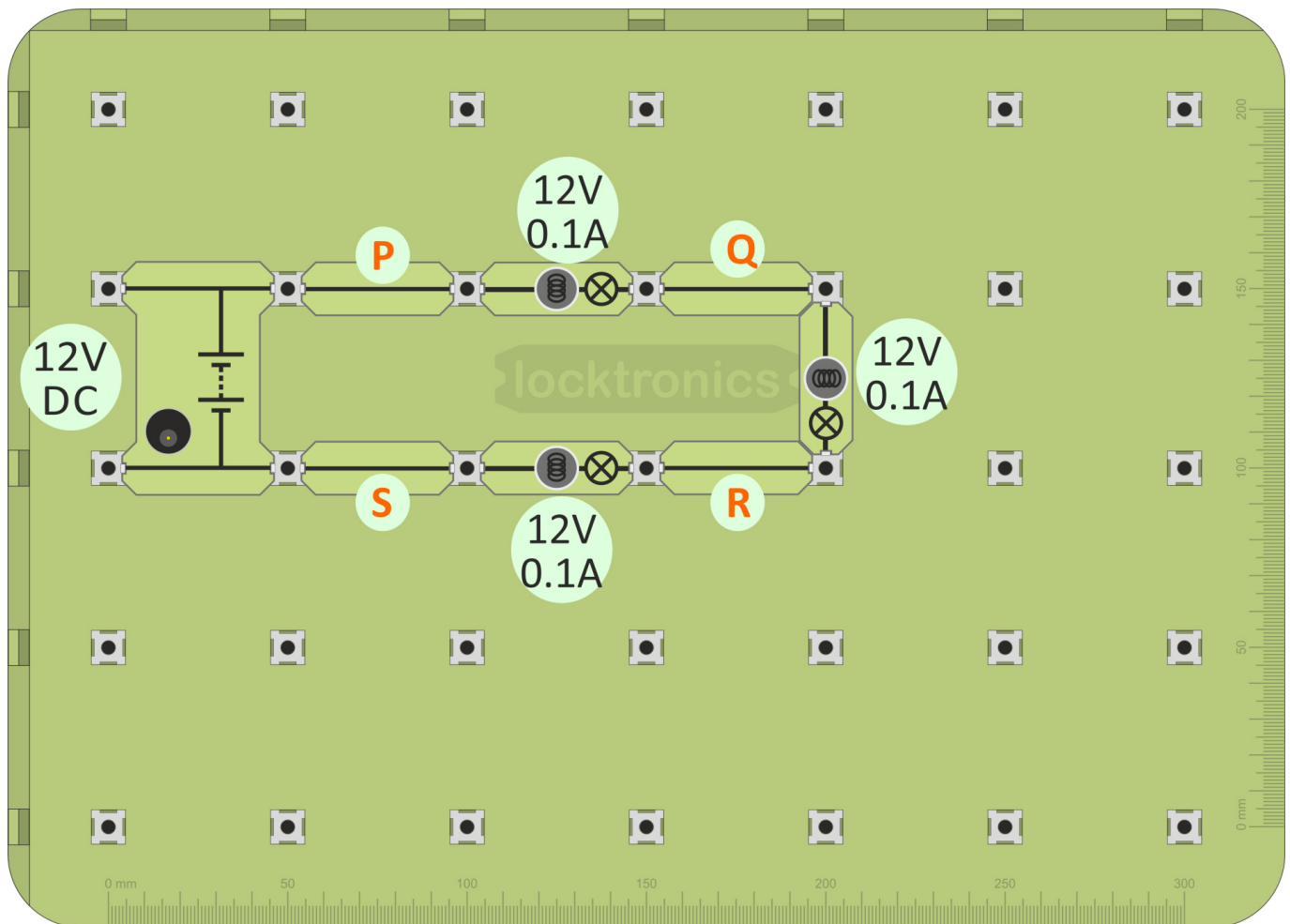


Using a multimeter to measure current:

- Plug one wire into the black 'COM' socket.
- Plug another into the red 'mA' socket.
- Select the 200mA DC range by turning the dial to the '200m' mark next to the 'A' symbol. (Again, it is best to set the meter on a higher range to begin with. Then choose a lower range to suit the current you find.)
- Break the circuit where you want to measure the current, by removing a link, and then plug the two multimeter wires in its place.
- Switch on the multimeter when you are ready to take a reading.
- A possible problem - The ammeter range is protected by a fuse located inside the body of the multimeter. This may have 'blown', in which case the ammeter will not work. Report any problems to your instructor so that it can be checked.

Measuring Current - 2

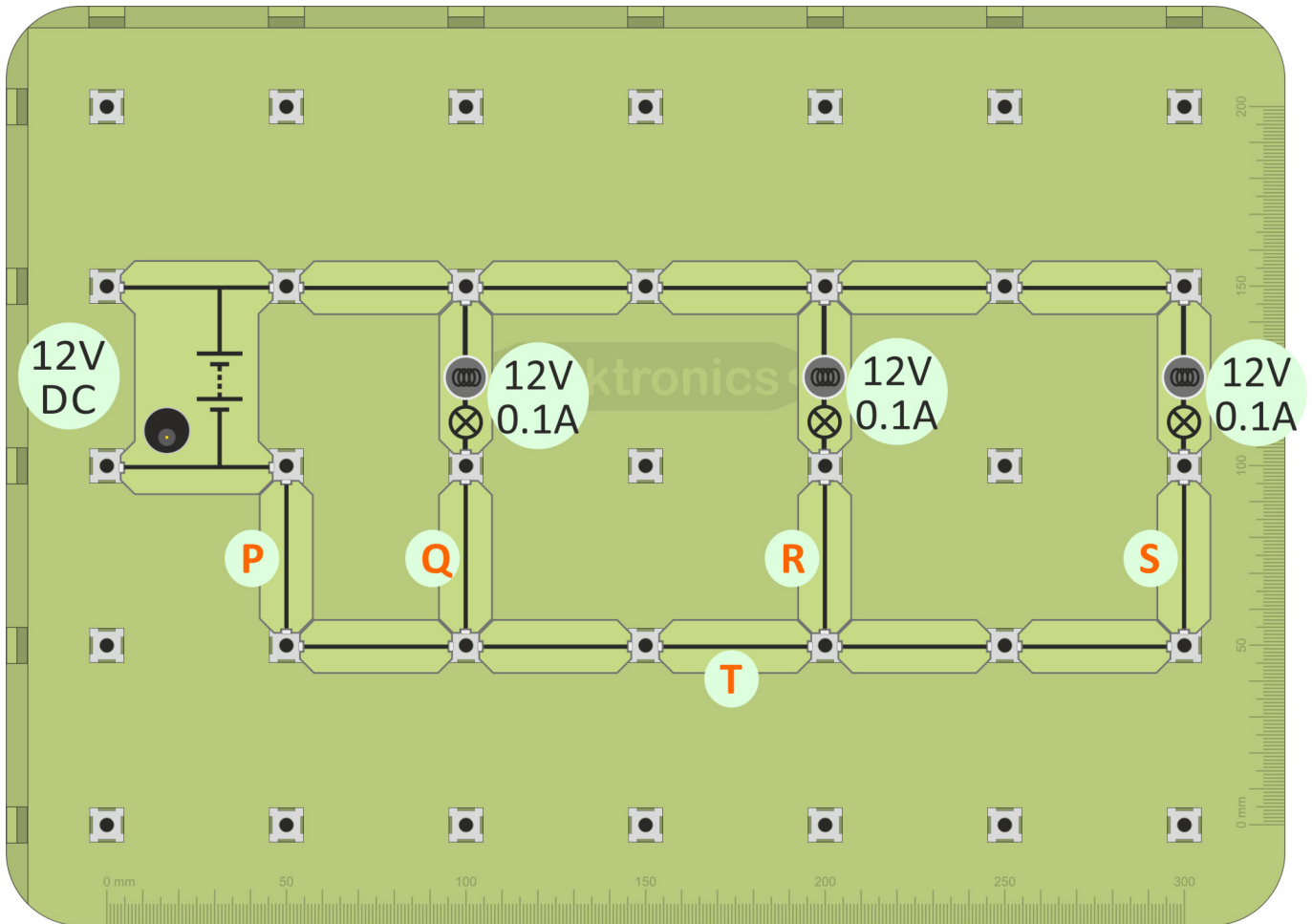
1. Build the layout shown below - a series circuit of three lamps but this time spread out to allow easy insertion of the ammeter when needed.
2. Connect the DC power supply, set to 12V, and switch on.



3. Set up the multimeter to read currents up to 200mA DC - see the previous page.
4. Measure the current at point 'P', by removing the connecting link and plugging the multimeter leads into the posts at either end of it.
5. In the same way, measure the current at points 'Q', 'R' and 'S'. You could say that the current at 'P' is the current delivered by the power supply, or the current flowing into the first bulb. Equally, the current at 'Q' is that leaving the first bulb, or entering the second one - and so on.
6. What do you notice about all the current readings?
7. Enter all your results into the table in the Student Handout and answer the question.

Measuring Current - 3

1. Build the layout shown below - a parallel circuit of three lamps, again spread out to allow easy insertion of the ammeter when needed.
2. Connect the DC power supply, set to 12V, and switch on.

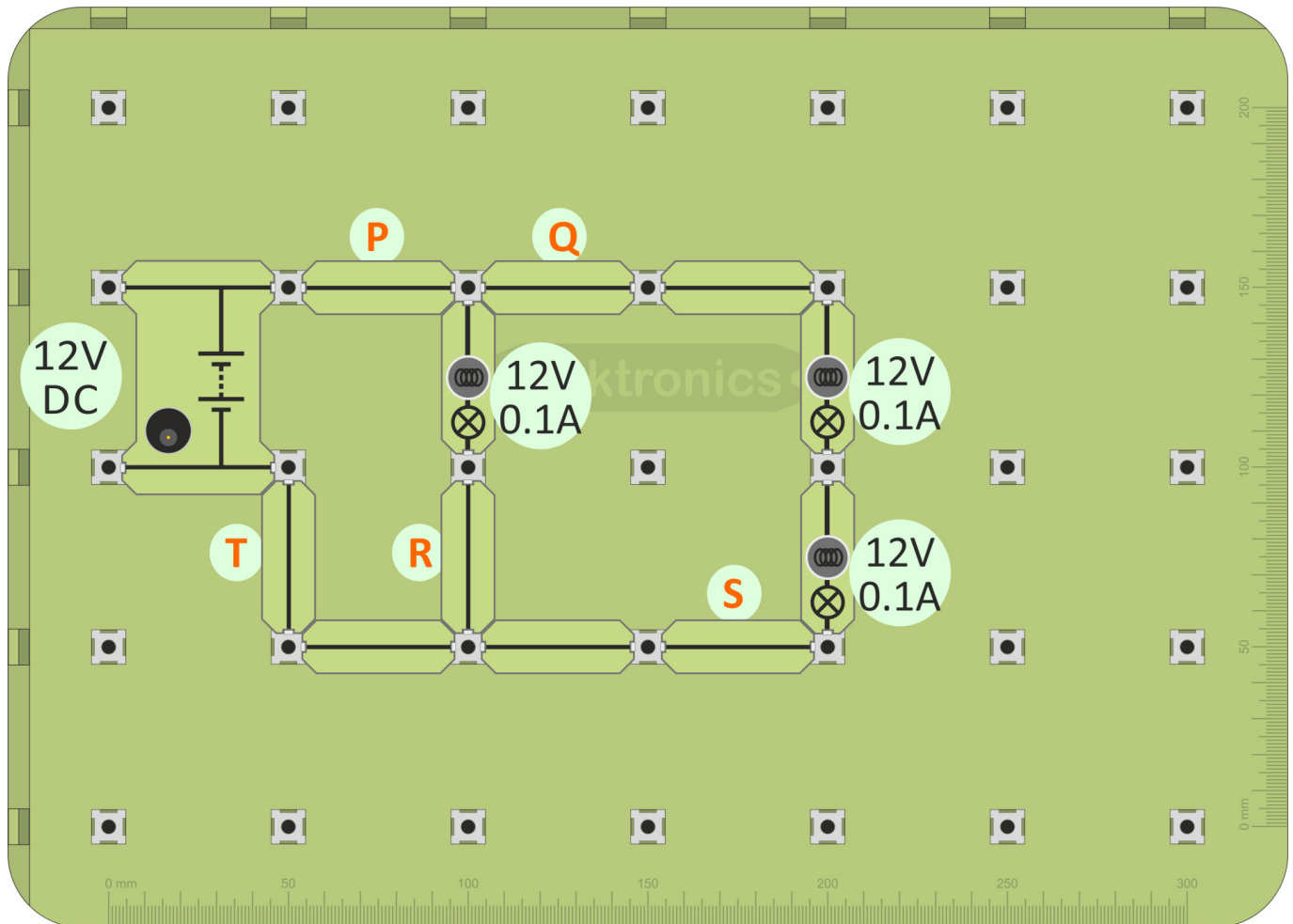


3. Set up the multimeter to read currents up to 200mA DC as before.
4. Measure the current at points 'P', 'Q', 'R' and 'S', by removing appropriate connecting links.
5. Enter your results into the table in the Student Handout and answer the question.
6. Use your results to estimate the current flowing at point 'T'.
7. Now measure it. Were you correct? Write its value in the Student Handout.

Measuring Current - 4

Now we look at the currents flowing in one of the circuits that have both series and parallel connections.

1. Build the layout shown below.
2. Connect the DC power supply, set to 12V, and switch on.



3. Measure the current at points 'P', 'Q', 'R', 'S' and 'T'.
4. Enter all your results into the Student Handout.
5. Explain why the current readings at points 'P' and 'T' are equal.
6. Explain why the current readings at points 'Q' and 'S' are equal. What does this imply for the brightness of the two bulbs between these points?
7. Compare these readings with the current at point 'R'. What does this mean for the brightness of the nearby bulbs?

Carry out a similar investigation on the other mixed circuit, built earlier.

Resistance - 1

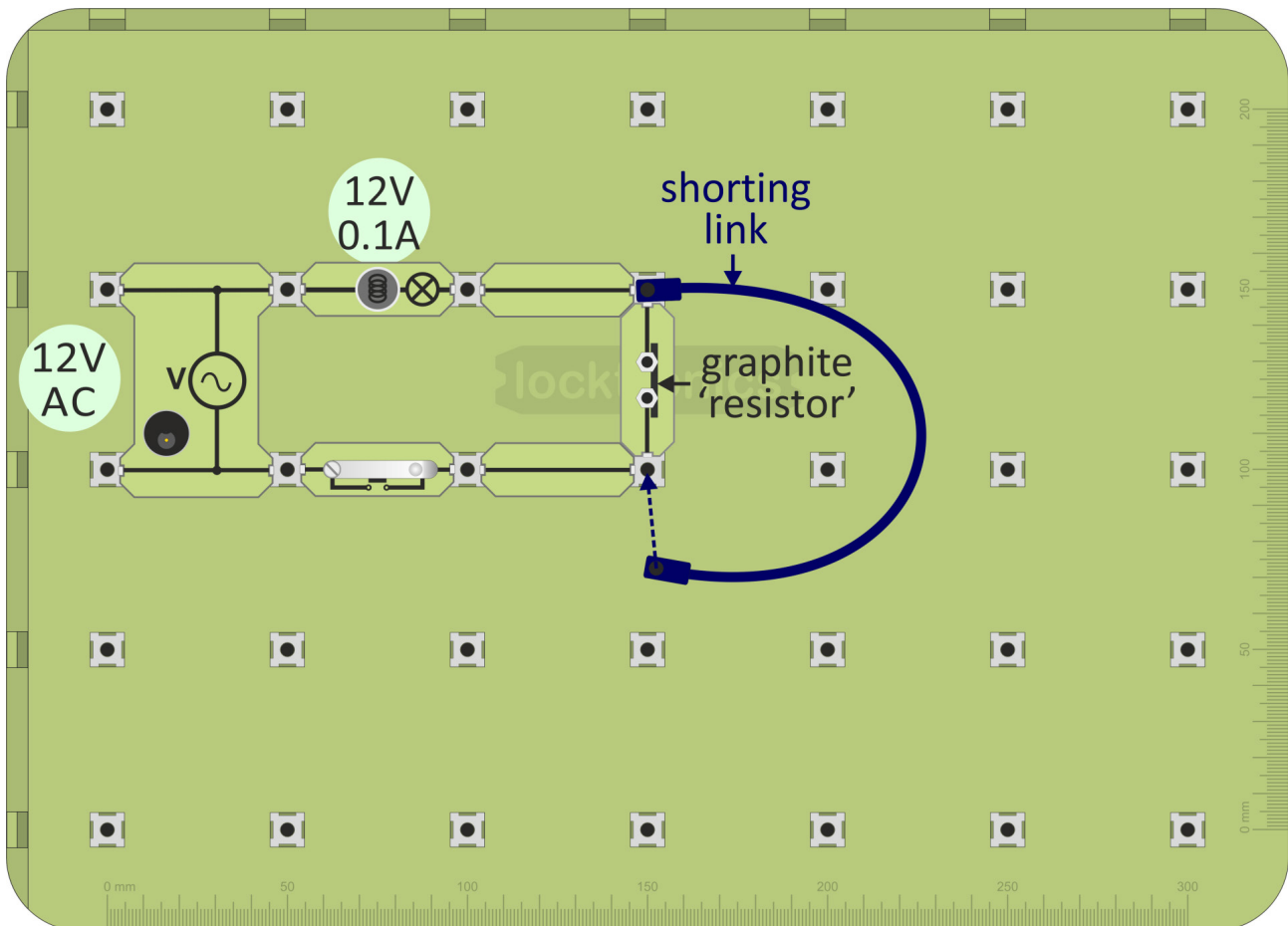
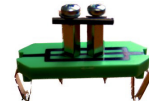
So far it has been on/off control of electric currents, using conductors or insulators. Now we want a more subtle control.



Using a tap, we can change the flow of water.

With electricity, we change the flow using a **resistor**.

1. Create your resistor, using a short length of graphite (pencil lead) in the universal component carrier.
2. Build the layout shown below.



3. Connect the 12V power supply and switch on.
4. Close the switch and notice how bright the bulb looks. Remember – the brighter the bulb, the greater the current flowing.
5. Next, 'short-circuit' the resistor by joining both ends with a wire, as shown. What do you notice about the bulb? What does this tell you about the electric current when you add the resistor?

Resistance - 2

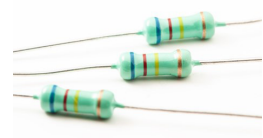
For electrons, adding resistance is like asking you to run in mud.

It takes more energy!

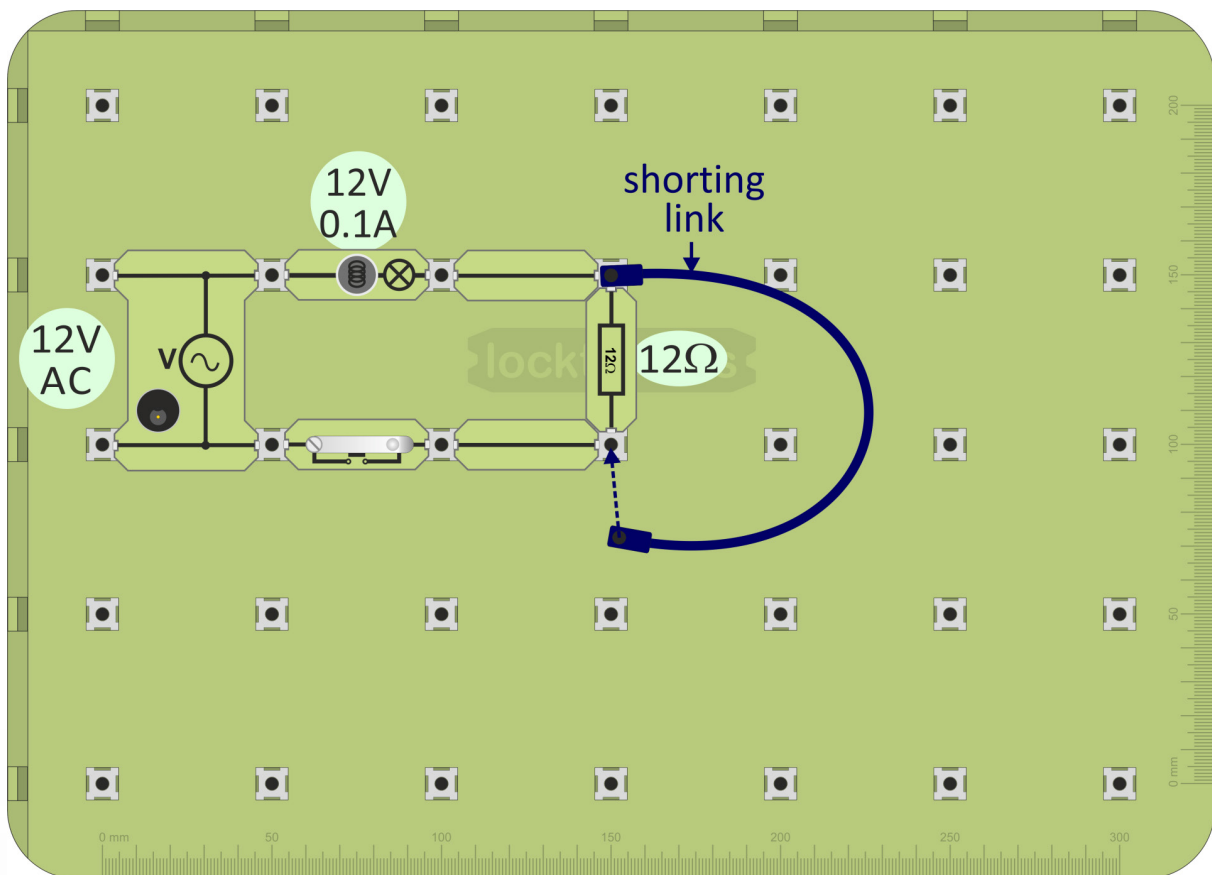


Commercially-made resistors often look like the one opposite.

The colour of the stripes is significant, but that is for later!



1. Build the layout shown below.
2. Connect the 12V power supply and switch on.



3. Close the switch and notice how bright the bulb looks.
4. Next, 'short-circuit' the resistor with the wire. What happens to the bulb? What does that tell you about the current?

Measuring Resistance - 1



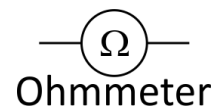
When using a multimeter to measure resistance, the component must be removed from the circuit first!

As before, before you switch on:

- Take care to plug the probes into the correct sockets, the 'Ω' and 'COM' sockets;
- Select the correct range.

Resistance:

- Is a hindrance to the flow of electrons around the circuit;
- Removes energy from each electron as it moves through the resistor;
- Converts this energy into heat;
- Is measured in units called 'ohms' (symbol - 'Ω') or kilohms (kΩ), by an ohmmeter. (1 kilohm = 1 000 ohms.)



Using a multimeter to measure resistance:

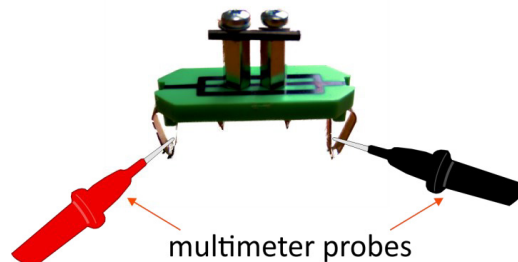
- Plug one wire into the black 'COM' socket.
- Plug another into the red 'Ω' socket.
- Turn the dial to select a resistance range, such as 200kΩ. (As before, it is good practice to set the meter on a range higher than the reading you are expecting and then refine it to a lower range.)
- Make sure that the component under investigation is not connected to any other.
- Plug the wires into the sockets at the ends of the component.
- Switch on the multimeter when you are ready to take a reading.

Measuring Resistance - 2

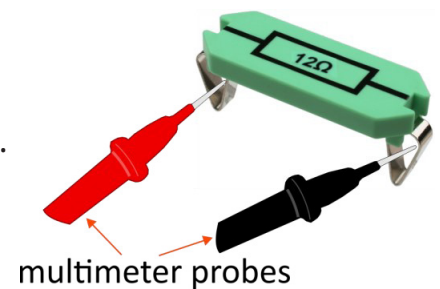
The first task is to measure the resistance of the home made resistor.

We expect this to have quite a low resistance, judging by its effect on the bulb earlier.

1. Set the multimeter on the 200Ω range.
2. Make sure that the probes are plugged into the ' Ω ' and 'COM' sockets.
3. Press the tips of the probes against the metal clips on the universal component carrier, as shown in the diagram.



4. Read the value of resistance shown on the multimeter.
5. Record this value in the Student Handout.
6. Next, do the same for the 12Ω carrier.
7. Record its value in the Student Handout as well.



Although we know what answer to expect, the value displayed is unlikely to be exactly 12Ω !

The quandary - is there some inaccuracy in the resistor, or is the multimeter not totally accurate?

(The answer is probably a little bit of both!)

The Energymeter

Energy:

- Many forms - heat, light, sound, electricity etc.;
- Measured in joules (J) or kilowatt-hours (kW-h);
- What we pay for, at filling stations, in electricity and gas bills etc.

Power:

- Energy used (or converted) per second;
- Measured in watts (W), or kilowatts (kW). (1 kilowatt = 1 000 watts.)

The energymeter:



- Measures voltage, current, power and energy consumption;
- Measurement chosen by pressing function button;
- 'Start / Pause' and 'Reset' buttons offer measurement of energy consumption over a period of time;
- Display adjusts to show appropriate units.

Using the energymeter to measure energy consumption:

1. Connect the energy source (battery, power supply, DC generator etc.) to the 'Source' terminals.
2. Connect the load (bulb, resistor, motor etc.) to the 'Load' terminals.
3. Plug in the energymeter power supply, and switch on. The display shows the word 'Initialising...' for a few seconds and then looks like the picture below.

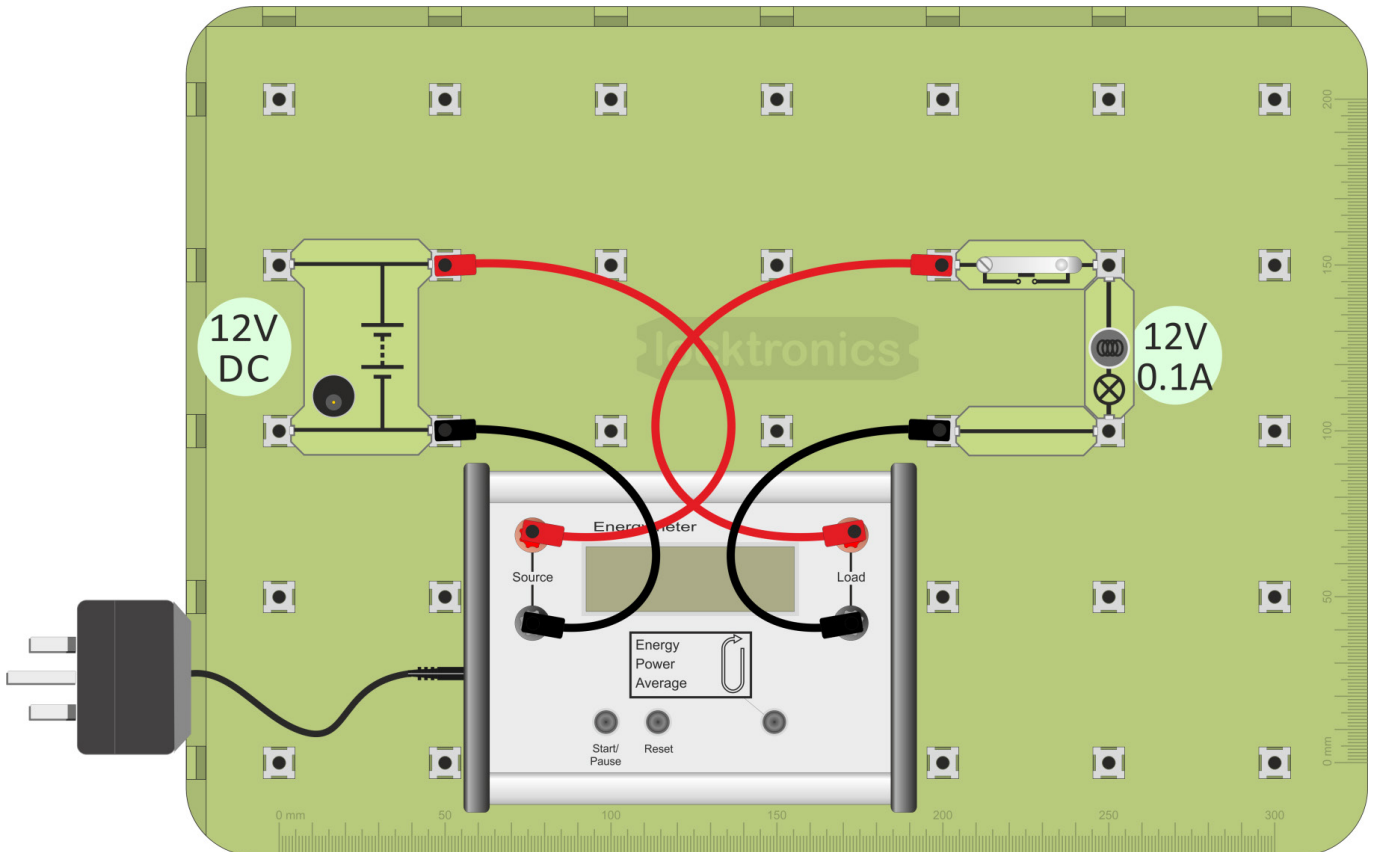
Energy	0J
Time	0s

4. Press the 'Start / Pause' button. The energymeter starts to record the energy transferred from the source to the load. The arrow at the lower right-hand corner of the display, shows that the meter is continuing to measure.
5. Press the 'Start / Pause' button again. The display freezes and the arrow turns to a 'P' to show that the meter has paused.
6. To clear the readings, press the 'Reset' button.

Measuring Power

1. Build the layout shown below.
2. Connect the 12V power supply and switch on.

Plug in the energymeter power supply, and switch on.



3. Press the 'Function' button until the display shows
4. Press down the push switch to make the bulb light.
5. The display now shows the power consumed by the bulb.
6. Record the reading in the Student Handout.

Modify the circuit to measure the combined power consumption of two bulbs, connected:

- In parallel;
- In series.

In each case record your results in the Student Handout.

Comment on your results.

Energy and Power

Energy:

- Comes from sources such as fossil fuels, the Sun, nuclear fission;
- Appears in many forms, heat, light, sound, electricity etc.;
- Is measured in units called joules (J) or kilowatt-hours (kW-h).

Power:

- Measures how much energy we use (or convert) each second;
- Is measured in watts (W), or kilowatts (kW). (1 kilowatt = 1 000 watts.)

For example:

- A 100W lamp is much brighter than a 40W lamp - it converts more electrical energy into light each second;
- A 3kW heater generates three times as much heat as a 1kW heater.

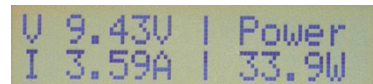
Calculating electrical power:

Use the formula: $P = I \times V$

meaning: **power = current x voltage.**

Example 1: What is the power rating of a bulb that takes a current of 0.25A from the mains 240V supply?

Power = current x voltage = $0.25 \times 240 = 60W$.



V 9.43V | Power
I 3.59A | 33.9W

Example 2: The energy meter displayed the readings shown in the picture.

The power measurement = current x voltage = $3.59 \times 9.43 = 33.9W$

In the UK, consumers are encouraged to use 'smart' meters, offering a range of functions including displaying the power dissipated in individual appliances or in the whole domestic installation.





STUDENT HANDOUT



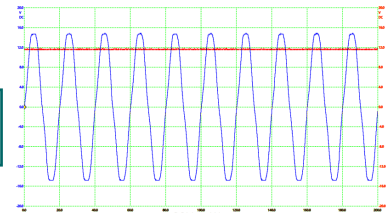
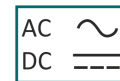
Student Handout

Page 7 - AC vs DC:

The 12V AC power supply has a rms voltage of

Page 8 - AC and DC again:

The graph compares the voltage / time behaviour of the AC and DC power supplies.



The symbols shown are used to distinguish between them.

Page 9 - Conductors and Insulators:

Materials that conduct	Materials that do not conduct

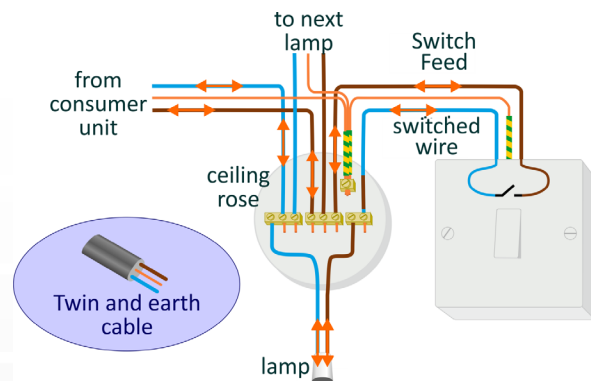
What do you notice about metals?

Page 11- Circuit diagrams - 2:

Which circuit draws the biggest current from the power supply - A, B or C?

Page 14 - Current path - 3:

The diagram shows how to wire up a pendant light to a ceiling rose and control it with a switch.



Student Handout

Page 16 - Heating effects:

When an electric current flows , its energy is converted to heat.

The filament lamp - The filament, usually made from tungsten, is heated to such a high temperature that it glows yellow-hot, giving out light. However, typically only ~5% of the electrical energy appears as light. LED (Light-Emitting Diode) lighting can be 10 times more efficient.

In a 'short-circuit', where worn or damaged insulation allows wires to touch, large currents can flow, causing a lot of heat. One solution is the fuse - a short length of wire with a low melting point, which acts as the weak point in the circuit. A large current flowing through it heats it so much that it melts, breaking the circuit and stopping the current before overheating more widespread damage.

The reverse process takes place in a thermocouple. When the junction of different metals is heated, it generates a DC voltage. This can be used to measure temperature.

Page 18 - Magnetic effects:

An electric current is ALWAYS accompanied by a magnetic field.

The principal application of the magnetic effect of electricity is the electric motor, widely used in domestic appliances. Other applications of electromagnetism include:

- Transformers - in power supplies, such as mobile phone chargers;
- Generators - used to power tools or as a stand-by in case of power cuts;
- Loudspeakers - in radios, televisions, computers and mobile phones;
- Circuit breakers - another protection against current overload and overheating.

Page 21 - Chemical effects:

An electric current can create/be created by a chemical reaction.

An electric current is a flow of electrons, (tiny particles found in all atoms.)

A chemical reaction involves electrons transferring between atoms.

Batteries illustrate the link between them. In a 'dry' battery, a chemical reaction generates a voltage which can drive an electric current. In rechargeable batteries, this process can be reversed - a current flowing the 'wrong' way can reverse the chemical reaction, storing up energy for later use.

In electroplating, an electric current through a chemical solution deposits a metal on one of the electrodes in order to protect it from corrosion or to improve its appearance.

Student Handout

Page 22 - Connect in series - 1:

In a series connection:

- Devices are connected one after the other in a line;
- There are no alternative routes - no branching;
- Only one path exists for the current through the connection.

What do you notice about the brightness of the three lamps connected in series?

What happens if you unscrew one of the bulbs?

Page 23 - Connect in series - 2:

How does the brightness of these lamps compare with the previous circuit?

What does this show about the current flowing in the circuit?

Does unscrewing a bulb have the same effect as in the previous circuit?

Page 24 - Connect in parallel:

In a parallel connection:

- Devices have their own separate 'branch-line';
- The ends of a device connect to corresponding ends of all other devices;
- Each device has its own path for the current through the connection.

What do you notice about the brightness of the three lamps?

How does their brightness compare the the three lamps connected in series?

What happens if you unscrew one of the bulbs?

Student Handout

Page 25 - Series / parallel - 1:

What do you notice about the brightness of the three lamps?

What happens when you unscrew bulb 'P'?

What happens when you unscrew bulb 'Q'?

Explain these differences:

Page 26 - Series / parallel - 2:

What do you notice about the brightness of the three lamps?

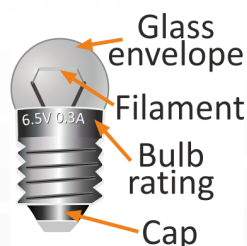
What happens when you unscrew bulb 'P'?

What happens when you unscrew bulb 'Q'?

Explain these differences:

Page 27 - MES bulbs:

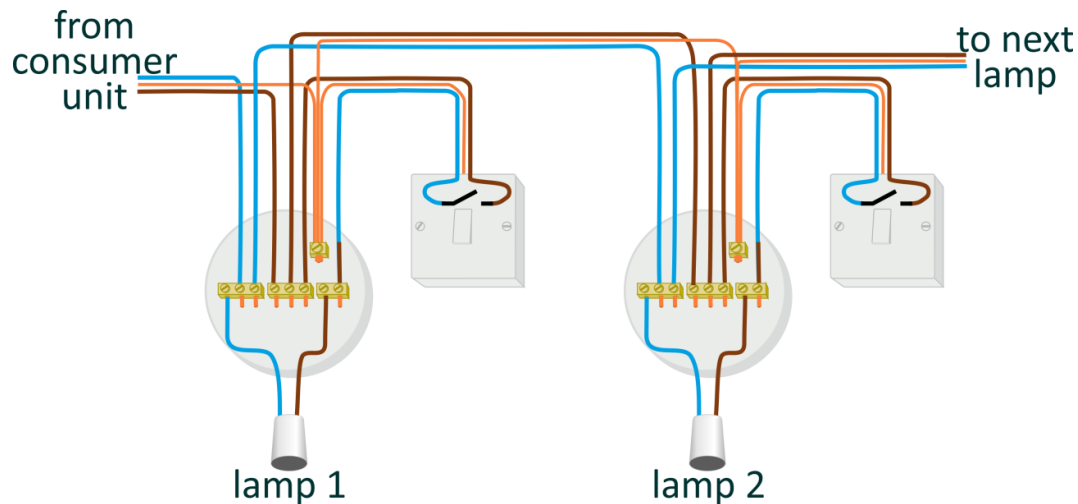
MES bulbs are mass-produced to reduce cost. As a result, they are not quite identical. They may have different filament lengths or diameters or experience different heat losses. Given identical conditions, they will not give the same brightness.



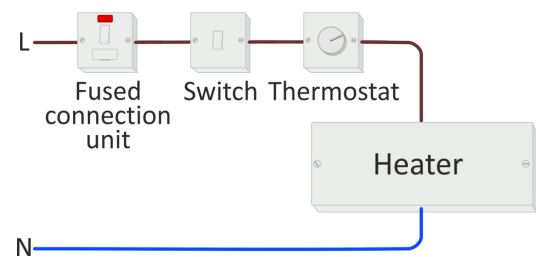
Student Handout

Page 28 - Serial / parallel applications:

In domestic lighting, it is important that lamps operate independently especially when one bulb 'blows'. Hence they are connected in **parallel**, as the diagram shows.

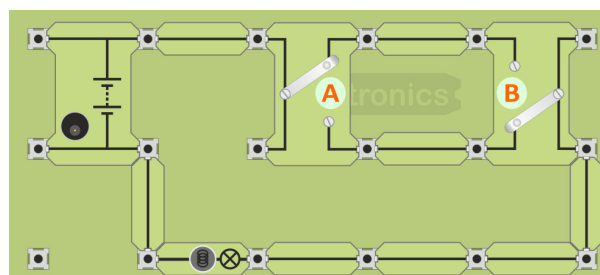


Controls, like fuses, switches and thermostats, must be able to 'break' the circuit and stop current flow to the load device, such as a heater. As a result, they are connected in **series** with the load.



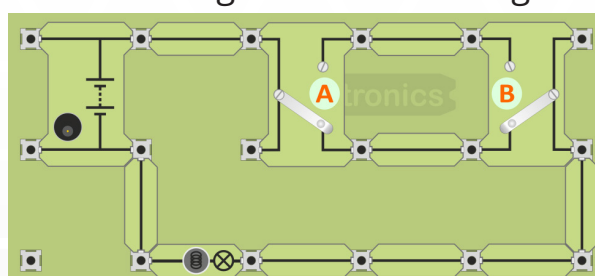
Page 29 - Staircase circuit - 1:

With switch A and switch B in the positions shown, is the bulb lit?



Switch A is moved to the other position, as the next diagram shows.

Draw the current path for this arrangement on the diagram.

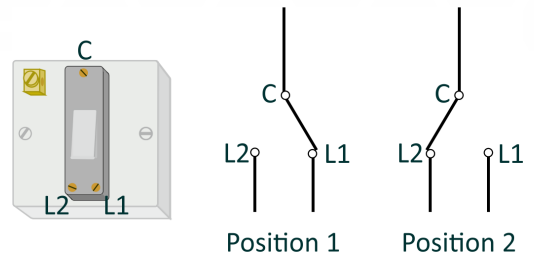


Student Handout

Page 30 - Staircase circuit - 2:

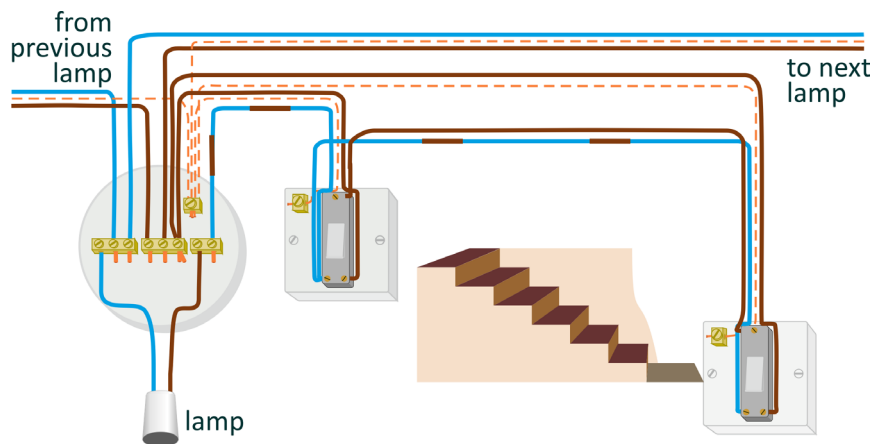
A changeover switch, also called a SPDT (single-pole-single-throw) switch, has three terminals: **C** (for Common), **L1** and **L2**.

Operating it connects **C** to either **L1** or **L2**.



In the 2-way switching circuit:

- **L1** terminals are connected ;
- **L2** terminals connected to each other and to the 'switched wire';
- **C** terminals are connected .



Starting with the incoming 'live' connection (brown) from the previous lamp:

- With the left-hand switch is in position 1, **L1** is connected to **C**, making it 'live';
- The **C** terminal in the other switch is connected to it, and so is also 'live';
- With the right-hand switch is in position 2, **L2** is connected to **C** and so is 'live';
- This makes the brown wire to the lamp 'live' and so the lamp lights.

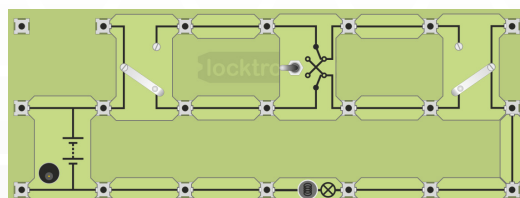
Page 31 - 3-way control - 1:

By adding a third switch - an intermediate switch, (also called a reversing or a DPDT (double-pole-double-throw switch,)) the lamp can be controlled by three switches.

The switches are in the positions shown.

The intermediate switch makes the connections shown on the carrier.

On the diagram, draw the current path.

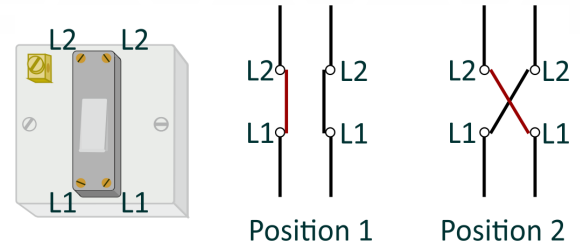


Student Handout

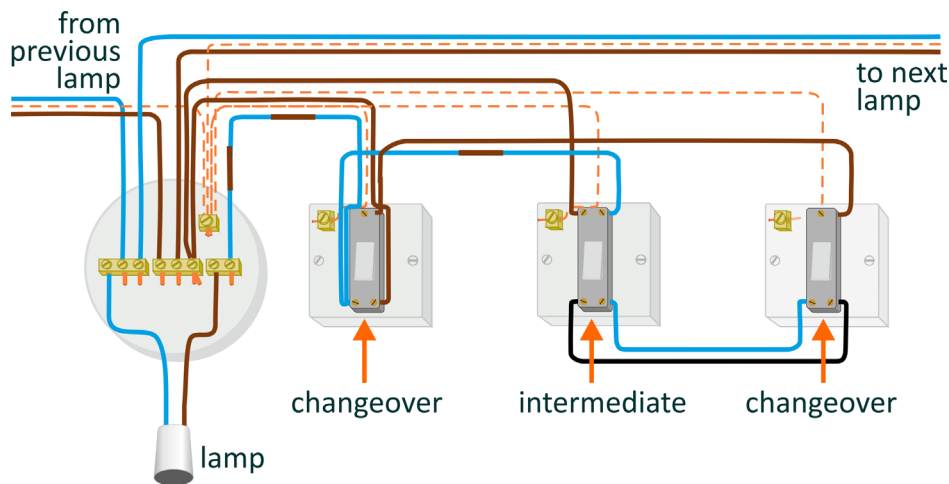
Page 32 - 3-way control - 2:

An intermediate switch has four terminals, two labelled L1 and two labelled L2.

Operating it makes the connections shown.



The three-way switching circuit is shown below:

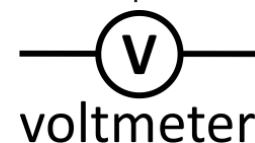


Page 33 - Measuring voltage - 1:

Voltage:

- Is a measure of the force pushing the electrons around the circuit;
- Measures energy lost or gained as an electron moves through part of a circuit;
- Is measured with a voltmeter connected in parallel with the component.

The circuit symbol for a voltmeter is shown opposite.



When using a multimeter, **before you switch it on:**

- Take care to plug the probes into the correct sockets;
- Select the correct range.

Using a multimeter to measure voltage:

- Plug one wire into the black '**COM**' socket and the other into the red '**V**' socket.
- Select the 20V DC range, (or a range much higher than the reading you expect.)
- Plug the wires into the sockets at the ends of the component under investigation.
- Switch on the multimeter when you are ready to take a reading.
- A '-' sign in front of the reading means that the meter wires are connected the wrong way round. Swap them over to get rid of it!
- Now select a lower range if that is appropriate.

Student Handout

Page 34 - Measuring voltage - 2:

Voltage between points	Reading
1 and 2 (Lamp 1)	
2 and 3 (Lamp 2)	
3 and 4 (Lamp 3)	
5 and 6 (Power supply)	

What do you notice about the sum of the voltages across the three lamps?

Page 35 - Measuring voltage - 3:

Voltage between points	Reading
1 and 2 (Lamp 1)	
3 and 4 (Lamp 2)	
5 and 6 (Lamp 3)	
7 and 8 (Power supply)	

Comment on these results:

Page 36 - Measuring voltage - 4:

Voltage between points	Reading
1 and 2 (Lamp 1)	
3 and 4 (Lamp 2)	
4 and 5 (Lamp 3)	
6 and 7 (Power supply)	

Comment on these results:

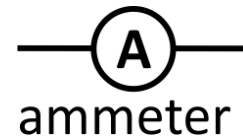
Student Handout

Page 37 - Measuring current - 1

Current:

- Measures the number of electrons passing any point in the circuit each second;
- Measures the rate of flow of electrical charge in the circuit;
- Is measured with an ammeter connected in series with the component.

The circuit symbol for a ammeter is shown in the diagram.



Using a multimeter to measure current:

- Plug one wire into the black '**COM**' socket and the other into the red '**mA**' socket.
- Select the 200mA DC range, (or a range higher than the reading you expect.)
- Break the circuit where you want to measure the current, by removing a link or component and plug the two multimeter wires in its place.
- Switch on the multimeter when you are ready to take a reading.
- Now select a lower range if that is appropriate.
- Beware - The ammeter range is protected by a fuse located inside the body of the multimeter. This may have 'blown', in which case the ammeter will not work.

Page 38 - Measuring current - 2:

Current at point:	Reading
P	
Q	
R	
S	

Comment on these results:

Student Handout

Page 39 - Measuring current - 3:

Current at point:	Reading
P	
Q	
R	
S	

Comment on these results:

Estimate of the current at point T:

How did you obtain this estimate?

Page 40 - Measuring current - 4:

Voltage between points	Reading
P	
Q	
R	
S	
T	

Why are the readings at points 'P' and 'T' equal?

Why are the readings at points 'Q' and 'S' equal?

Student Handout

What does this imply for the brightness of the two bulbs between these points?

Which bulb is the brightest?

Page 41 - Resistance - 1:

We control the flow of electricity using a resistor.

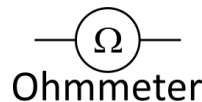
What effect does adding the resistor have on the brightness of the bulb?

What does this tell you about the effect of adding the resistor on the current?

Page 43 - Measuring resistance - 1:

Resistance:

- Is a hindrance to the flow of electrons around the circuit;
- Removes energy from each electron as it moves through the resistor;
- Converts this energy into heat;
- Is measured in units called 'ohms' (symbol - ' Ω ') or kilohms ($k\Omega$), by an ohmmeter.
(1 kilohm = 1 000 ohms.)



When using a multimeter to measure resistance, the component must be removed from the circuit first!

Student Handout

Using a multimeter to measure resistance:

- Plug one wire into the black 'COM' socket and the other into the red Ω socket.
- Turn the dial to select a resistance range, such as 200k Ω (or a range that is much higher than the reading you are expecting.)
- Make sure that the component under investigation is not connected to any other.
- Plug the wires into the sockets at the ends of the component.
- Switch on the multimeter when you are ready to take a reading.
- Now select a lower range if that is appropriate.

Page 44 - Measuring resistance - 2:

Resistance of 'home-made' resistor = Ω .

Resistance of Locktronics resistor carrier = Ω .

Page 45 - The energymeter:

Energy:

- Comes from sources such as fossil fuels, the Sun, nuclear fission;
- Appears in many forms, heat, light, sound, electricity etc.;
- Is measured in units called joules (J) or kilowatt-hours (kW-h).

Power:

- Measures how much energy we use (or convert) each second;
- Is measured in watts (W), or kilowatts (kW). (1 kilowatt = 1 000 watts.)

For example:

- A 100W lamp is much brighter than a 40W lamp - it converts more electrical energy into light each second;
- A 3kW heater generates three times as much heat as a 1kW heater.

Page 46 - Measuring power:

Power consumed by one lamp =

Power consumed by two lamps in parallel =

Power consumed by two lamps in series =

Comment on these results:

Page 47 - Energy and power:

To calculate electrical power, use the formula: $P = I \times V$
(meaning : **power = current x voltage.**)

Example:

Calculate the power rating of a bulb taking a current of 0.25A from the 240V mains.

Power = current x voltage = $0.25 \times 240 = 60\text{W}$.

[illegible]

[illegible]

[illegible]

ELECTRICAL INSTALLATION 1

CP4098

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