locktronics

Simplifying Electricity

Electricity matters 1

CP7325

MATRIX

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Worksheet 1

Conductors and insulators

We are surrounded by many kinds of materials. They all behave in different ways.

One way in which they are different is that some pass electricity, and others do not.

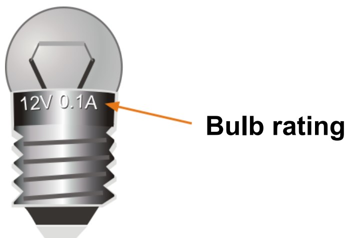
Materials which pass electricity are called **conductors**.
Materials which do not pass electricity are called **insulators**.

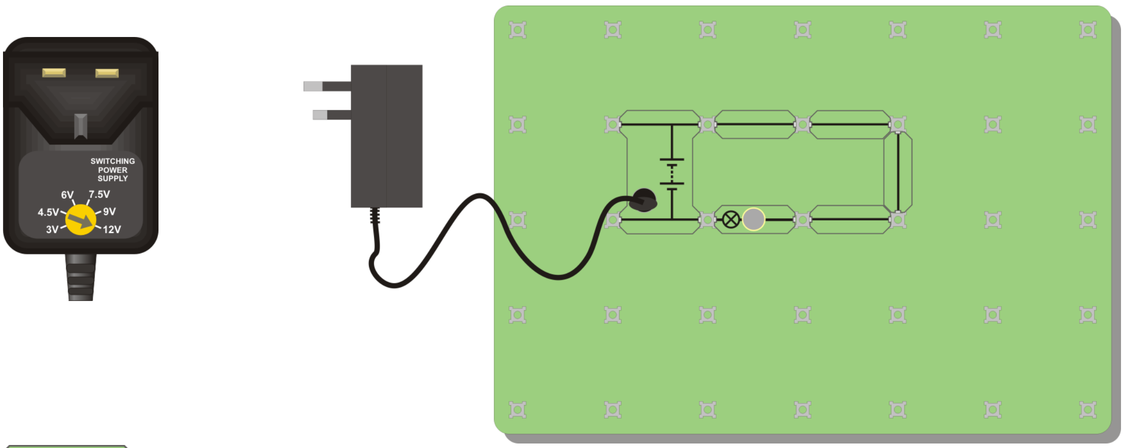
Over to you:

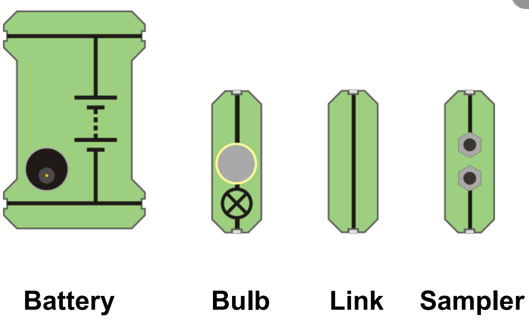
Build a circuit that makes a bulb light.
The picture shows one way to do this.

Set the power supply to 12V.

Use a 12V 0.1A bulb. (See the picture!)



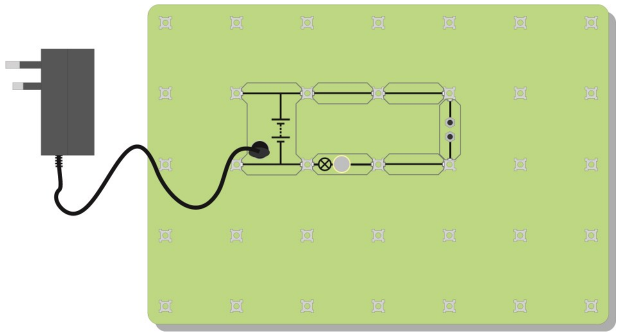




Here are the names of some of the components that you will use on the board.

Worksheet 1
Conductors and insulators

Swap one link for the carrier with the sampler.
Your board now looks like the picture.



Put different materials across the gap, in turn.
See if the bulb lights.
Try 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
any other handy items.

Sort the materials into two groups –

conductors and **insulators**.

Fill in a table, like the one shown here, with the findings from your experiment.

Materials that conduct	Materials that insulate

So what?

- Look at the materials that let electricity pass.
- Which class of substance do they all belong to?
- If you had a hard, shiny object that felt cold to touch, would you expect it to be a conductor? Explain your answer to your partner or to your teacher.
- Think of a way to test whether water is a conductor or an insulator. Check your idea with the teacher, and if you get the go-ahead, try your idea out.
- Test pure water, tap water (they are not the same thing!) and salty water. Is there a difference?

For your records:

- Most of the conductors belong to the class of substances called ....
- I think that the hard shiny object that felt cold would .... electricity, because it is probably made of a ....
- Pure water is an .... However, if there are any impurities in it, such as salt, or chlorine, then the water is a ....
- Air is an .... which explains why we do not get an electric shock when we stand near a mains electricity socket.

Worksheet 2

Circuits

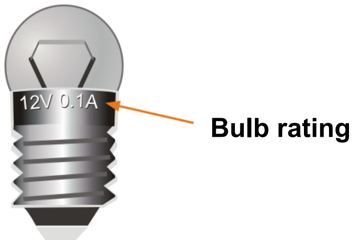
A roller coaster goes round a circuit.
It finishes at the same place as it starts.

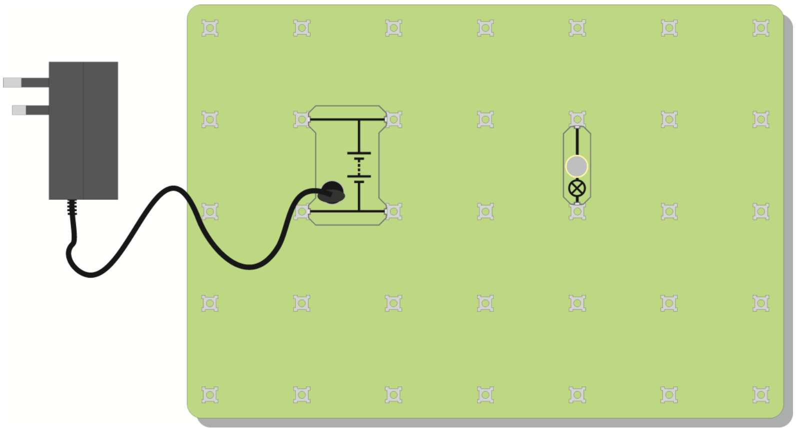
Electricity is the flow of invisible particles called electrons.
They go round a track of wire.

We call electric pathways - **circuits**.

Over to you:

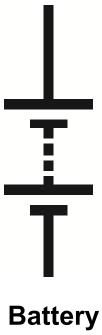
Set up the arrangement shown, using a 12V 0.1A bulb.
Make sure that the power supply is set to 12V.
Add connecting links to make the bulb light.

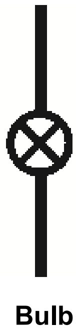




You have just used two circuit symbols, one standing for a battery, or group of batteries, and the other for a lamp, or sometimes any kind of indicator.

We will look at more of these symbols in later worksheets.
You should try to learn them as you use them.

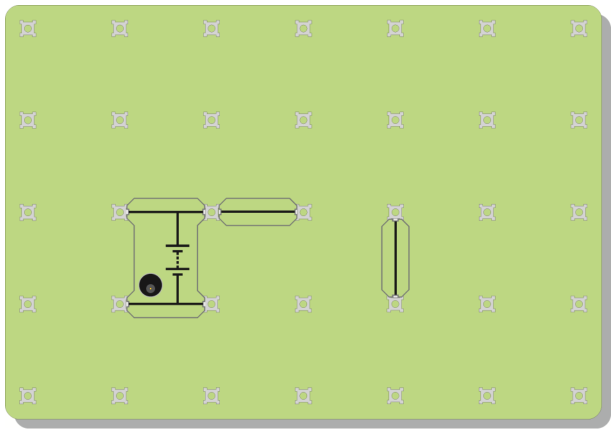




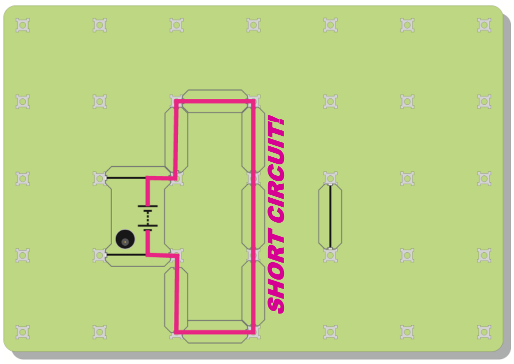
Worksheet 2
Circuits

Make other shapes with the links to make the bulb light.

You could try to complete the arrangement shown here.



w2e



w2d

BE CAREFUL!

Don't create a short circuit, where the electricity can get from one side of the power supply to the other without going through the bulb.

This might damage the power supply!

The diagram opposite shows an example of a short-circuit.

So what?

- You need a complete circuit to make the bulb light. There must be an unbroken path of conductors going from the power supply to the bulb and then back to the power supply.
- The actual shape of the circuit makes no difference.
- Can you set up a circuit to make two bulbs light?
  There are two ways to do this. One way makes the bulbs dimmer than when there was just one bulb. The other way keeps roughly the same brightness as in the one-bulb circuit.
  Can you make both of these circuits?

For your records:

For a bulb to light, there must be:

- a source of ...., such as a battery or power supply;
- wires of metal to .... the electricity;
- wires which are insulated by a .... coating to stop the metal conductors touching each other;
- a complete ...., with no gaps in it.

Worksheet 3

Electric current

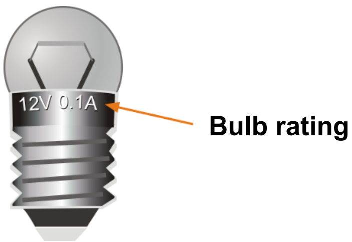
We use electricity in many ways, not just for lighting bulbs.
It heats our homes, drives our washers, driers and vacuum cleaners, and powers our computers, games and phones.

Electric currents warm up the wires that they flow through.

Over to you:

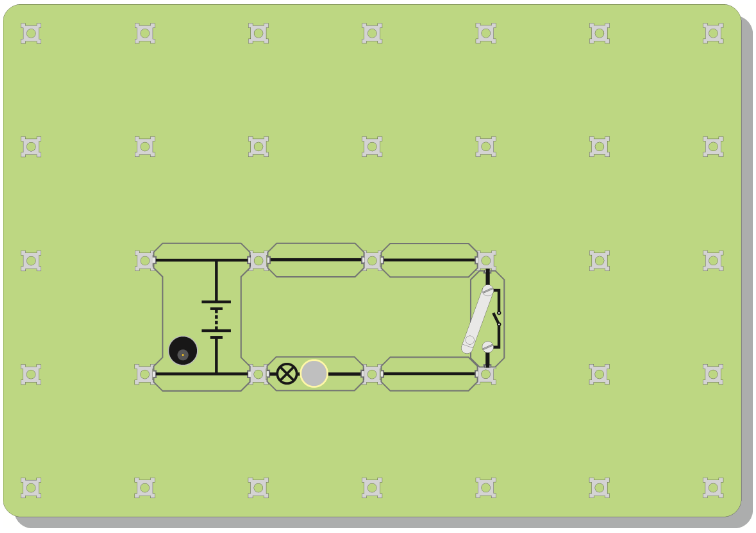
Set up the arrangement shown in the diagram below, using a 12V 0.1A bulb.

Make sure that the power supply is set to 12V.

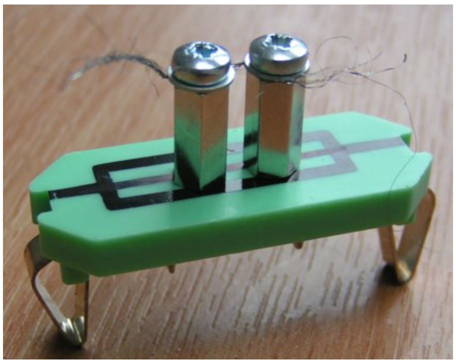


w1a

Switch on by closing the switch.
Look at the lamp filament. It should be glowing yellow-hot.
Take hold of the glass envelope of the lamp.
Does it feel warm?
Switch off.



w3b



Tease out one or two strands of wire wool from the pack.

Carefully clamp them across the gap of the sampler, as shown in the photograph.

w3c

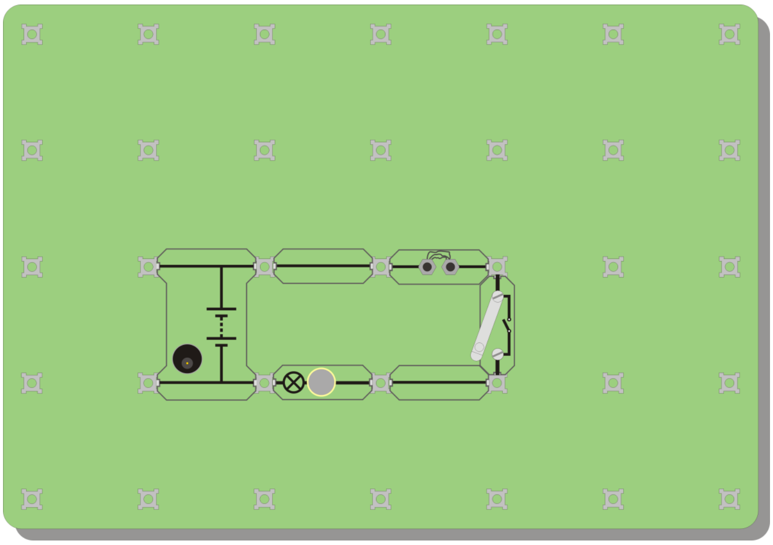
Worksheet 3

Electric current

Modify your circuit, as shown opposite, by swapping one of the connecting links for the sampler.

Switch on by closing the switch.

What happens?



So what?

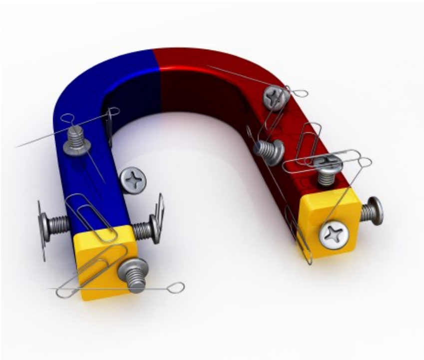
- An electric current can heat things up.
- Some kinds of wire heat up more than others.
- Some wires get so hot that they glow. This is what is happening inside some kinds of light bulb. In fact this kind of light bulb gives out more heat than light!
- Find out as much as you can about low-energy light bulbs.
  Explain to your partner why it is a good idea to use these instead of ‘normal’ light bulbs (the ones that get very hot!)

For your records:

- When an electric .... flows through wires, it warms them up.
- Some kinds of wire get so hot that they ....
- One kind of light bulb, called a filament lamp, uses this effect to produce light.
- They are expensive to run because they give off more ....
  than ....

Worksheet 4
Electromagnetism

w4a



We use electricity in many ways, not just for lighting bulbs.

It heats our homes, drives our washers, driers and vacuum cleaners, and powers our computers, games and phones.

Electric currents can make wires behave like magnets!

Over to you:

Set up the arrangement shown in the diagram, using a 12V 0.1A bulb, and the mounted coil .

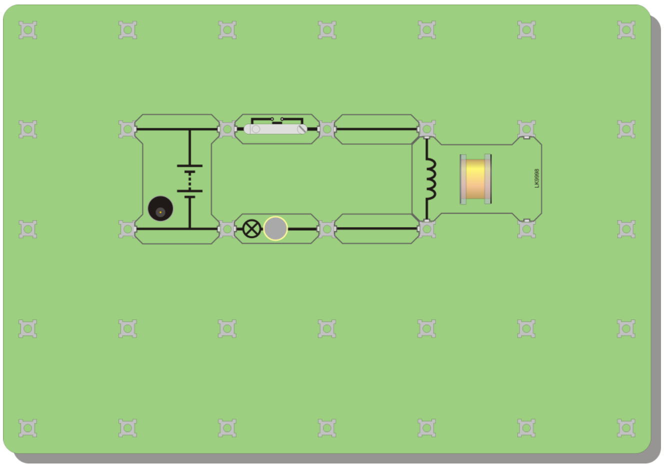
Make sure that the power supply is set to 12V.

Place a magnetic compass next to the coil.

Turn the board so that the compass needle points across the opening of the coil.

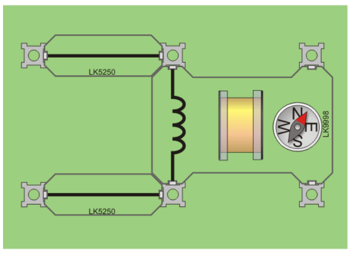
Press the switch. What happens?

Now switch off and repeat this again.



w4b

w4c



Wave a magnet near the compass.

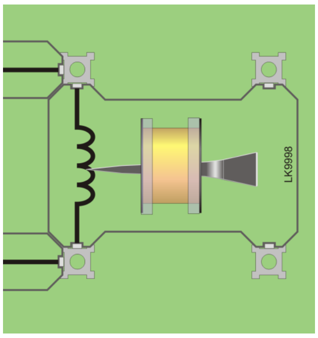
What happens?

What does this show about the coil when it was carrying a current?

Worksheet 4
Electromagnetism

So what?

- An electric current can make the coil behave the same as a magnet.
- Slide a steel nail inside the coil.
  Switch on the power supply and watch the magnetic compass.
  Is the effect stronger than before?
- See if you can make paper clips stick to the nail.
- Try the same experiment using an iron nail instead of a steel nail.
  Can you see any difference?
  (Look carefully at what happens after you have switched off the electricity, in both cases.)
- How do you think you could make the magnetic effect stronger?
  Explain your ideas to your teacher. You may be able to try your ideas out!



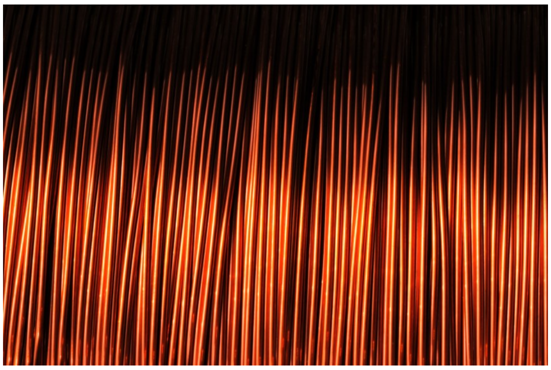
w4d

For your records:

- When an electric current flows through a wire, it produces a .... effect.
- The effect is stronger if you form the wire into a coil and push a nail, made of .... or ...., down the centre.
- The nail then behaves like a .... It affects a compass needle, and can even pick up paper clips.
- Two ways to make the magnetic effect stronger are:
  - add more ....;
  - increase the ....

Worksheet 5

Electrolysis



Electric currents cause a number of effects. They can:

- heat up the cables they pass through.
- produce magnetic effects.
- cause chemical reactions to take place.

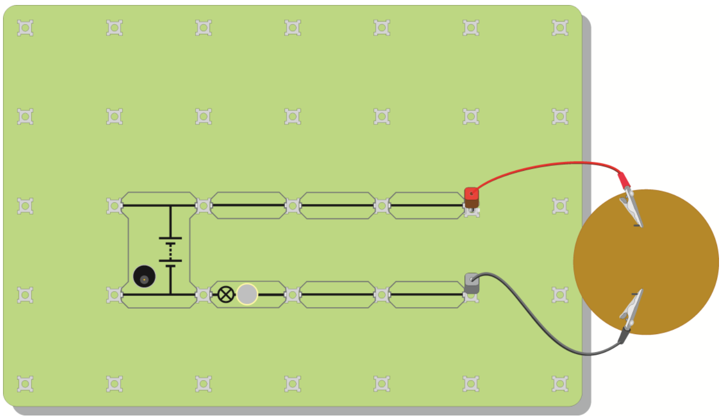
In industry, processes such as electrolysis and electro-plating rely on these chemical reactions.

Electric currents can cause chemical reactions!

Over to you: (optional experiment)

Set up the arrangement shown in the diagram as follows:

- Carefully push the two graphite pencil leads through the hardboard disc, as shown. Take care not to snap them!
- Wear your goggles to protect your eyes.
- Pour about 200ml of copper sulphate solution into a 250ml beaker. The concentration of copper sulphate used here is not hazardous, but make sure that you wash your hands at the end of the investigation.
- Lower the graphite rods into the beaker, so that the hard-board disc sits on top of the beaker.



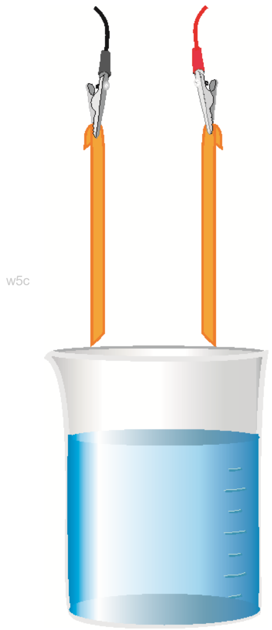
- Connect two electrical leads to the rods using crocodile clips. Again, take care not to snap the rods!
- Connect the circuit shown in the diagram, using a 12V 0.1A bulb. The lamp is included so that you can see when a current is flowing.

Worksheet 5
Electrolysis

Watch carefully to see if anything is happening in the beaker.

You should see two events taking place.

Notice which electrode (graphite rod) is involved.



Here is another example of a chemical reaction produced by an electric current.

This time, the electrodes are both strips of copper.

Once again, connect the electrodes to the circuit shown earlier.

Watch carefully to see what happens!

So what?

An electric current can cause a chemical reaction.

What did you see to make you think that a reaction was taking place?

How could you check that an electric current was flowing?

How can you make sure that the reaction was caused by the electric current?

Discuss your ideas with your partner, and then explain what you think to your teacher.

Come up with a plan to test your ideas. The teacher may be happy for you to go ahead and try out your plan.

For your records:

An electric current can cause a chemical reaction to take place.

This effect is very useful in the chemical industry.

It is used to purify chemical substances, and produce new ones.

The applications of this effect include **electrolysis** and **electroplating**.

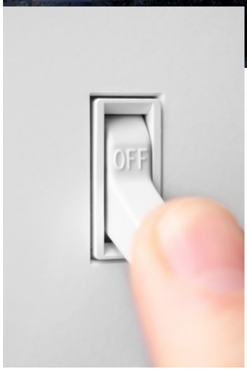
Worksheet 6
Switches

Have you ever been told not to leave lights on?

Leaving them on wastes energy, and money!

We need something to control the flow of electricity.

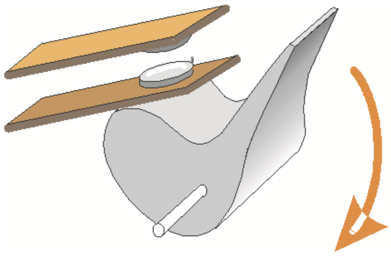
A switch does just that!



Look at the drawing! It shows how a switch works.

Can you see what will happen when you press the switch and the lever moves down?

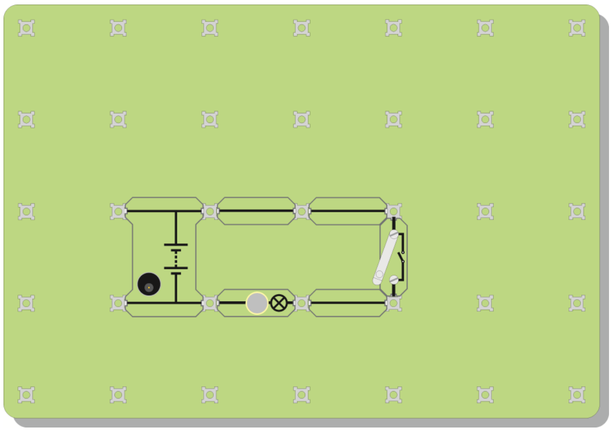
Remember – air is an insulator!



A switch starts and stops the flow of electricity.

Over to you:

Set up the arrangement shown in the diagram, using a 12 V power supply and a12V 0.1A bulb.



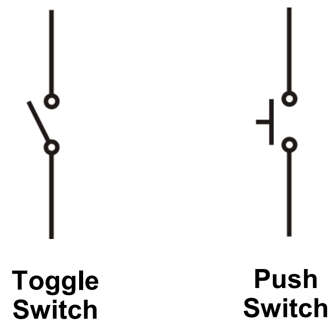
Close the switch, and see what happens.

Change the circuit so that there are two bulbs in it, and the switch controls both bulbs.

Now change the circuit again so that the switch controls only one bulb.
The other bulb should be lit all the time.

Worksheet 6
Switches

The diagram on the right shows the symbols used for two kinds of switch.
A push switch is ‘on’ only as long as you are pressing it. When you turn on a toggle switch, it stays on, until you turn it off.
Here are two pictures of switches—a doorbell switch, and a light switch. Decide whether each is a toggle switch or a push switch.



So what?

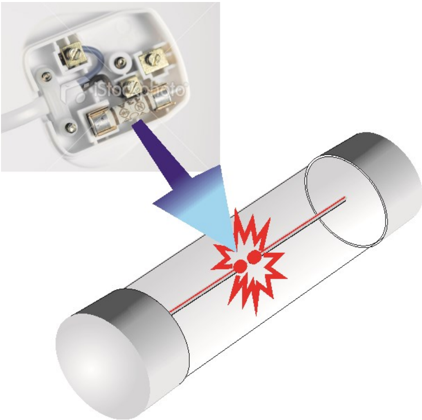
- A switch starts and stops the flow of electricity.
  What stops the electricity from flowing when the switch is open?
- Does it matter where the switch is placed in the circuit shown in step 1?
  Explain the answer to your partner, and then do an investigation to see if you were right.

For your records:

- A switch starts and stops the flow of ....
- When the switch is open, the .... gap stops the flow of electricity.
- When the switch is ...., the air gap disappears, and electricity flows around the circuit.
- A toggle switch stays on or stays off all the time. A push switch is on only as long as you press it.
- A doorbell is one type of .... switch.
- A light switch is one type of .... switch.

Worksheet 7

The fuse



Electricity can be dangerous.

The low voltage you are using in your experiments is safe, but the high voltage used in the mains electricity supply can kill.

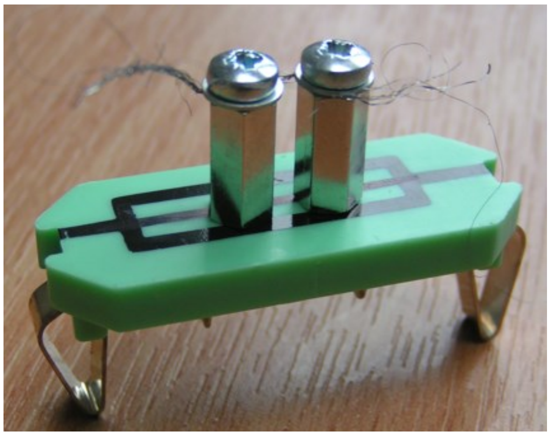
If there is a problem in a mains circuit, the wires can get so hot that they set the house on fire.

We need a safety device!

Fuses protect us when electrical gadgets are faulty.
They prevent fires when electrical faults occur.

Over to you:

Clamp one or two fibres of steel wool between the terminal pillars of the sampler.



Build the circuit shown in the next diagram, using a 12V power supply and a 12V 0.1A bulb.

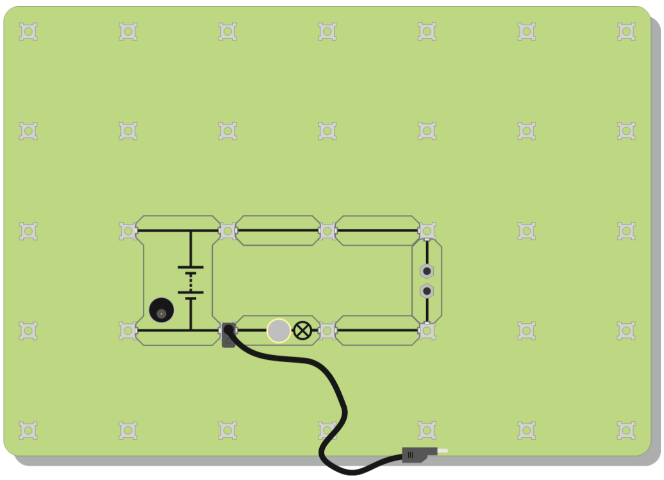
Leave one end of the black lead loose. Make sure that it does not touch any part of your circuit.

Close the switch and make sure that the bulb lights.

Now create a fault in the circuit.

Touch the loose end of the wire lead onto the right hand side of the bulb, for a moment.

You just short-circuited the bulb. What happens?



Worksheet 7

The fuse

This diagram shows the symbol used for a fuse.

Fuse

w7b

So what?

- The fine fibre of steel wool gets hotter than the other wires. In fact, it gets so hot that it melts.
  Try to find out from the internet what temperature steel melts at.
- Once the fibre melts, there is an air gap in the circuit, rather like when a switch is open. No electric current can flow.

For your records:

- A fuse contains a fine metal wire.
- When the flow of electricity gets too big, this metal gets so hot that it ...., and breaks.
- This creates an air .... in the circuit, which stops the flow of electricity.
- This stops the other .... in the circuit from getting too hot, and causing a fire.

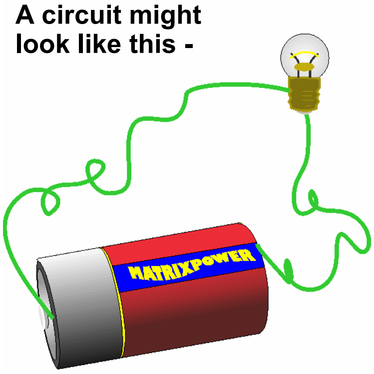
Worksheet 8
Symbols and circuits

Everyday you come across **symbols**, used at home or when you are out and about. They are quicker to read than long messages using words!

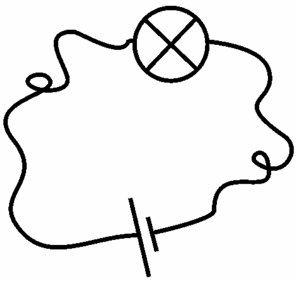
In this sign the language may be difficult to understand, but the symbols are not!

Circuit symbols are used to describe which components are used in a circuit, and how they are connected.

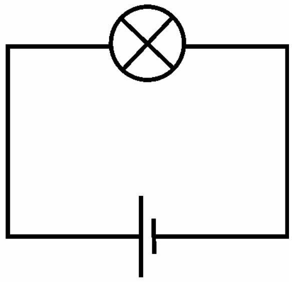
A circuit might look like this -

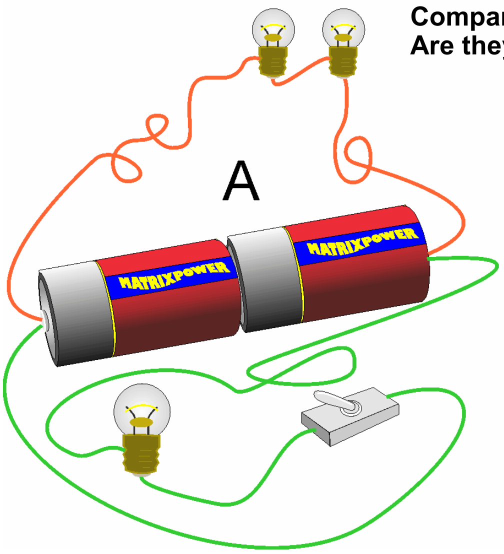


It is simpler to use symbols -

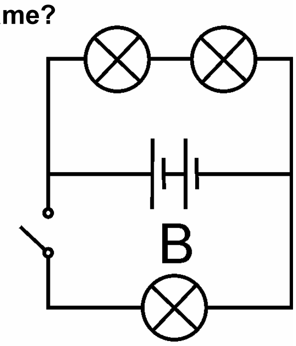


Or better still -





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

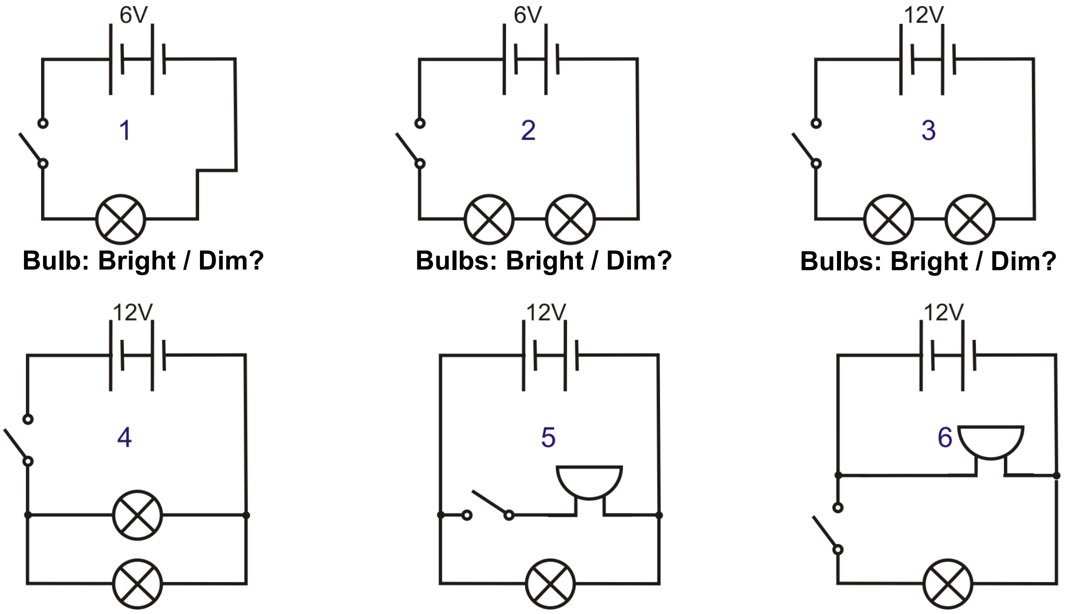


Worksheet 8

Symbols and circuits

Over to you:

Build the circuits shown in the next diagram, using 12V 0.1A bulbs.
The power supply voltage is given in each circuit diagram.
Work out the answers to the questions.



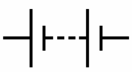
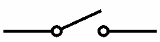
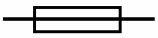
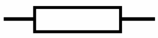
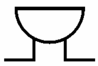
1: **Bulb: Bright / Dim?**
2: **Bulbs: Bright / Dim?**
3: **Bulbs: Bright / Dim?**
4: **Bulbs: Bright / Dim?**
5: **Switch controls .... ?**
6: **Switch controls .... ?**

So what?

It is much quicker and easier to describe what is in a circuit by drawing a diagram using symbols. However, you must use the symbols that everyone understands.

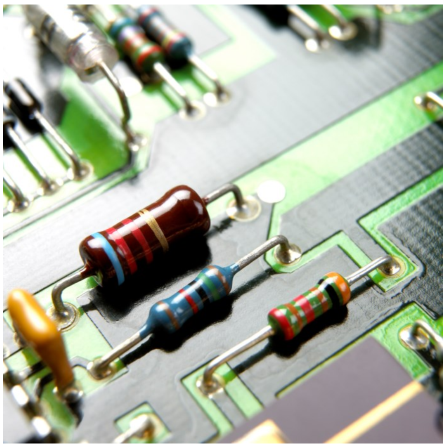
For your records:

Copy the following table.
You have seen the buzzer, or sounder, in the circuits above.
You will learn about the resistor soon.

					
Battery	**Toggle switch**	**Lamp**	**Fuse**	**Resistor**	**Sounder**
Supplies electrical energy	**Allows a circuit to work**	**Turns electricity into light**	**A safety device**	**Controls the size of the current**	**Turns electricity into sound**

Worksheet 9

Resistors



Using a tap, we can change the flow of water from fast to slow.

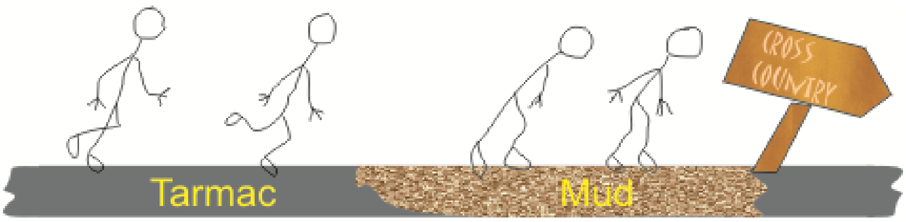
With electricity, we change the flow using a resistor.

The second picture shows resistors connected in a printed circuit board.

Electric currents can cause a variety of effects – heating, lighting, magnetism and chemical.

Although we cannot see them, tiny particles called electrons make up electric currents. The flow of these electrons can be reduced by adding more resistance to the circuit.

The effect of resistance is like you trying to run in mud.



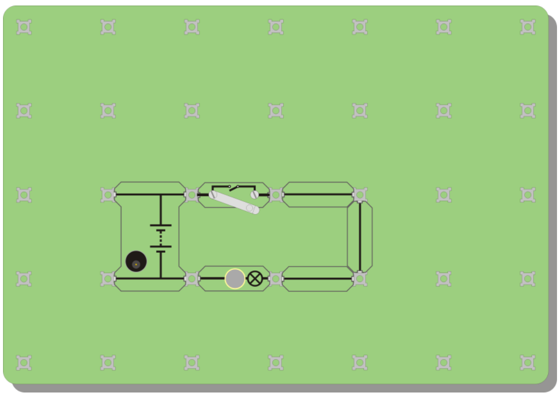
Over to you:

Make your own resistor by clamping a rod of graphite (a mixture of carbon and clay, used in pencil lead,) using crocodile clips onto the ends of two connecting leads . The rod should be as long as possible, and at least 15cm long.

Set up the circuit shown on the right, using a 12V 0.1A bulb.

Close the switch and notice how bright the bulb looks.

Remember – the brighter the bulb, the greater the current flowing.



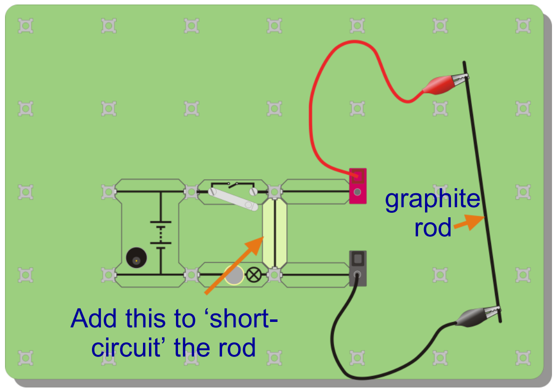
Worksheet 9

Resistors

Next, swap your pencil lead resistor for one of the connecting links and then close the switch again.

What do you notice about the bulb? What does this tell you about the electric current when you add the resistor?

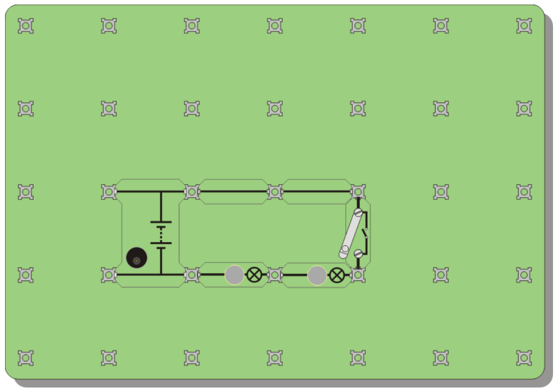
(You could make it easier to compare by ‘short-circuiting’ your resistor. To do this, add a connecting link as shown in the diagram.)



Now set up the circuit shown in the next diagram, using two 12V 0.1A bulbs.

Close the switch.

What do you notice about the brightness of the two bulbs compared to the brightness of the single bulb in the first circuit (before you added your resistor)?



So what?

- Adding more resistance to a circuit makes the electric current smaller.
- It is not only ‘resistors’ that have resistance – pencil lead, bulbs, even the wires themselves and the power supply have some resistance.
- Swap one of the bulbs for a 12 ohm resistor.
  Notice the brightness of the remaining bulb. What does this tell you about bulbs?
- A good question – where does the ‘extra’ electric current go when you add a resistor?
  Think about the flow of other things, like water, or traffic. When you turn a tap down a little to lower the flow of water, where has the ‘missing’ flow of water gone?
  When a car breaks down on a busy road, the flow of traffic is reduced. Where is the ‘missing’ flow of cars?

For your records:

- A resistor limits the flow of electricity.
- The bigger the resistance, the smaller the electric current.
- Resistance is measured in ohms. Usually, we use the Ω sign to mean ‘ohms’.
- The symbol used for a resistor is shown opposite:

Resistor

Worksheet 10

Bulbs in series and parallel

locktronics™

We use sat-nav (satellite navigation) systems to plan our route when travelling by car. These powerful electronic processors look at the many possible routes and choose the best.

In some electrical circuits, there is only one possible route, and all the electricity must flow around it. These are called **series** circuits.

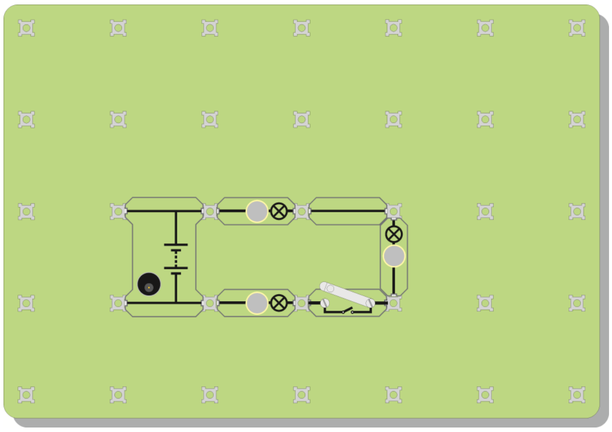
w10c

A **series** circuit offers only one route around the circuit, from one end of the battery back to the other! There are no junctions in a series circuit.

Over to you:

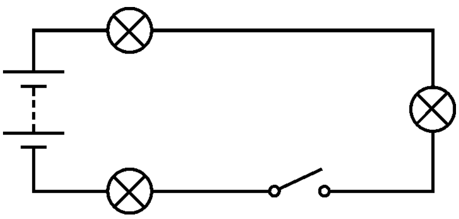
Set up the arrangement shown, using a 12 V power supply and 12V 0.1A bulbs.

This is a series circuit—everything connected in a line, one after the other. There is only one way for electric current to get from one end of the battery to the other. There are no junctions, no alternative routes!



w10a

w10d



Here is the same circuit, drawn using symbols,
Compare the two versions of the same circuit diagram!

Close the switch and notice how bright the bulbs look.
Don't forget – the brighter the bulb, the greater the current flowing.

Unscrew one of the bulbs and notice the effect.

Does it look as if electric current is getting 'used up' as it goes round the circuit?
(In other words, do the bulbs get dimmer as you move further from the battery?)

If the bulbs have the same brightness, then the current flowing through them must be the same. (Remember - the bulbs are mass-produced, and so are never completely identical.)

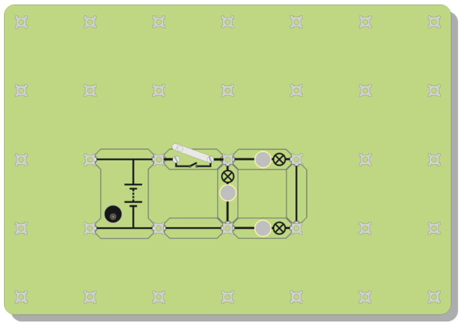
Worksheet 10

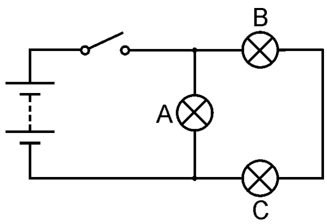
Bulbs in series and parallel

Now change the circuit for the one shown, still using the 12V setting on the power supply and 12V 0.1A bulbs.

This is not a series circuit—there are two ways to get from one end of the battery to the other!

Trace these routes out for yourself.





The ‘blobs’ above and below bulb A mark junctions in the circuit.

Look at the brightness of the bulbs. What does this tell us?

Unscrew bulb A. What happens?

Unscrew bulb B. What happens?

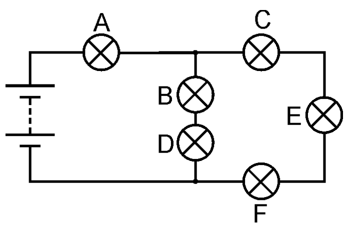
So what?

- One route goes through only one bulb. The other goes through two bulbs. That route is twice as difficult for the electrons. Most will take the easy route through just one bulb. The more electrons flow per second, the greater the electric current.
  Explain to your partner or your teacher how your observations support this idea.
- The second circuit is not a series circuit as there are two ways to get from one side of the battery to the other. Bulb A is connected in parallel with the other two bulbs. Bulb B is in series with bulb C because they are on the same route.
- **A challenge!**
  Change the circuit so that the switch controls only bulbs B and C, **BUT** you can only move bulb A.

For your records:

- A series circuit offers only one route for the electric current. If a break appears anywhere in the circuit, then the electric current stops everywhere. If one bulb fails in the circuit, then all the bulbs go out. The electric current is the same size throughout the circuit.
- A parallel circuit offers more than one route and so different currents can flow in different parts of the circuit.
- Copy the circuit diagram and answer these questions:

  1. Bulb B is in series with bulb ....
  2. Bulb C is in .... with bulb E and bulb F.
  3. Bulbs B and D are in .... with bulbs C, E and F.
  4. The biggest current will flow through bulb ....
  5. Bulb .... will be the brightest bulb.



Quiz

locktronics

Round 1

Name three materials which pass electricity.

Which of these is an insulator? Copper, mercury, rubber, tin.

What happens to the fine wire in a fuse when it ‘blows’?

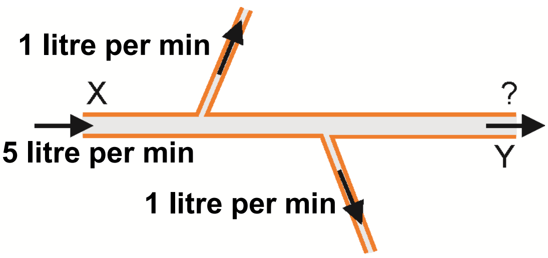
When a switch is open, what substance stops electricity flowing?

An electric current can produce a magnetic effect, a heating effect and a chemical effect.
Which of these effects is used in a filament light bulb, like the one shown in the picture?

Q0

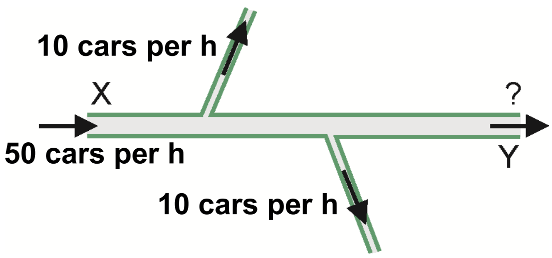
Round 2

Q2water



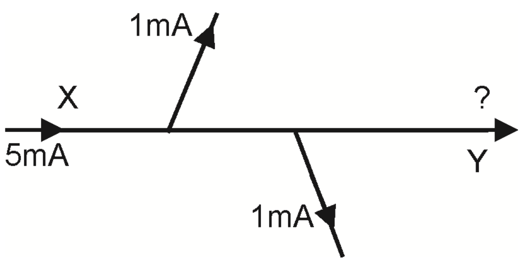
Here is a pipe, carrying water. It does not leak!
Five litres of water enter the pipe at X every minute.
Some water flows down the side pipes, as shown.
How many litres per minute leave the pipe at Y?

Here is part of a one-way system of roads, carrying only cars!
There are no crashes! No-one parks! There are no car factories or garages!
How many cars leave the system at Y each hour ?



Q2cars

Q2elec



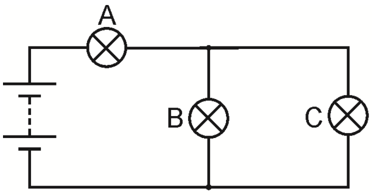
Here is part of an electric circuit.
Electric current is measured in units called milliamps, (mA).
How big is the current at Y?

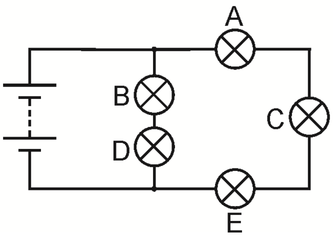
Electric currents are made up of millions of electrons flowing down the wires. These questions suggest that electric circuits do not leak, and that electrons do not crash or park, and are not made in factories, even on a Sunday!

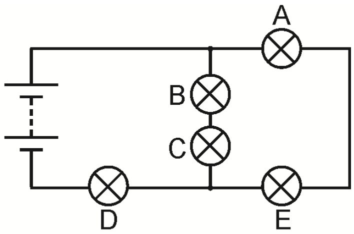
Quiz

Round 3

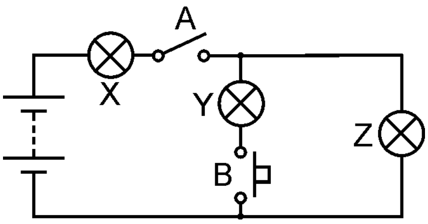
In the next three circuit diagrams, all the bulbs are identical.
Which bulb, or bulbs, will be the brightest in each of the circuits?





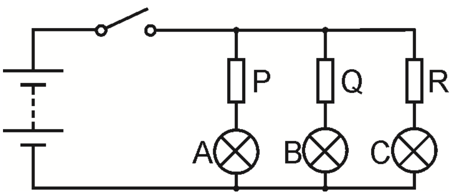


Round 4



Look at the circuit opposite.
To begin with, only switch A is closed (switched on.)
Which bulb, or bulbs, light(s)?
Next switch B is closed as well as switch A.
Which bulb, or bulbs, light(s) now?

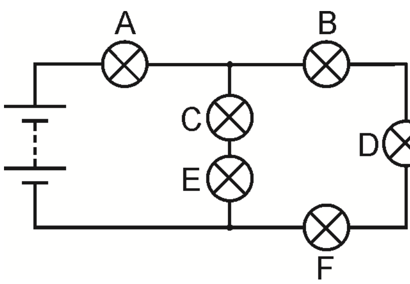
Round 5



When the switch is closed, bulbs A and C have the same brightness. Bulb B is dimmer than they are.
What can you say about resistors P, Q and R?

Round 6

To begin with, all the bulbs are lit.
One bulb fails, and all the bulbs go out.
Which bulb failed?
That bulb is replaced with a new one.
Then bulb C is unscrewed.
Which bulbs are still lit?



About this course

Introduction

The course is essentially a practical one. Locktronics equipment makes it simple and quick to construct and investigate electrical circuits. The end result can look exactly like the circuit diagram, thanks to the symbols printed on each component carrier.

Aim

The course aims to introduce pupils to the basic concepts in electricity.

Learning Objectives

On successful completion of this course the pupil will have learned:

- the difference between the electrical properties of conductors and insulators;
- how to test whether a material conducts electricity readily or not;
- the need for a complete circuit for conduction to take place;
- that an electric current can cause a significant heating effect;
- that an electric current can cause an appreciable magnetic effect, which is intensified by coiling the conductor, and using a core of magnetic material ;
- that an electric current can cause chemical reactions;
- the meaning of a range of electrical symbols;
- to construct a simple electrical circuit from a circuit diagram;
- that the shape of a circuit has no effect on its behaviour;
- to recognise a series connection and recall its properties;
- to recognise a parallel connection and recall its properties;
- the effect of resistance on the size of the current flowing;
- that resistance is measured in ohms;
- to recognise and avoid a short-circuit situation;
- the function of a switch in an electrical circuit;
- how to place a switch to control only part of a circuit;
- the function of a fuse in an electrical circuit.

Teacher's notes

What the student will need:

This pack is designed to work with the Locktronics Electricity, magnetism and materials kit.

The contents of this kit can be seen in the table on the right. Not all are used in this pack, as some will be used in the 'Electricity matters 2' pack.

Students will also need either:

the Locktronics 0 - 15V voltmeter carrier and 0 - 100mA ammeter carrier;

two multimeters, one capable of measuring currents in the range 0 to 100mA, the other measuring voltages in the range 0 to 15V;

or an ammeter capable of measuring currents in the range 0 to 100mA, and a voltmeter capable of measuring voltages in the range 0 to 15V.

If you are missing any components then please contact Matrix or your local dealer.

1	**HP4039**	**Tray Lid**
1	HP2666	Adjustable DC power supply
1	HP5540	Deep tray
1	HP7750	Daughter tray foam cutout
1	HP9564	62mm daughter tray
1	LK3246	Buzzer, 12V, 15mA
1	LK3982	Voltmeter, 0V to 15V
1	LK4002	Resistor, 100 ohm, 1W, 5% (DIN)
1	LK4100	Resistor, 12 ohm, 1W, 5% (DIN)
1	LK4102	Motor, 12V, open frame
2	LK5202	Resistor, 1k, 1/4W, 5% (DIN)
1	LK5203	Resistor, 10k, 1/4W, 5% (DIN)
1	LK5214	Potentiometer, 10k (DIN)
1	LK5243	Diode, power, 1A, 50V
9	LK5250	Connecting Link
3	LK5291	Lampholder, MES
1	LK5402	Thermistor, 4.7k, NTC (DIN)
1	LK5405	Relay, reed, normally open
1	LK5570	Pair of leads, red and black, 600mm, 4mm to croc clip
1	LK6207	Switch, push to make, metal strip
1	LK6209	Switch, on/off, metal strip
1	LK6231	Resistor, 50k, 1/4W, 5% (DIN)
1	LK6430	LED, red, 12V (SB)
1	LK6492	Curriculum CD ROM
1	LK7290	Phototransistor
1	LK7936	Fuse/universal component carrier
1	LK8275	Power supply carrier with battery symbol
1	LK8397	Ammeter, 0A to 1A
1	LK8900	7 x 5 metric baseboard with 4mm pillars
1	LK9070-56	Electricity, magnetism and materials solution inlay (DIN)
1	LK9071-AP	EMM V2 Accessories pack
1	LK9998	400 Turn coil carrier

Bulbs:

The kit comes with 12V 0.1A bulbs. The bulb rating is stamped on the body of the bulb, as shown in the diagram.

Bulb rating

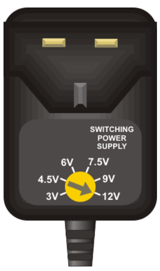
Power source:

The worksheets are written for the adjustable DC power supply, which can output voltages of either 3V, 4.5V, 6V, 7.5V, 9V or 12V, with currents typically up to 1A.

The voltage is changed by turning the selector dial just above the earth pin until the arrow points to the required voltage.

The teacher may decide to make any adjustment necessary to the power supply voltage, or may allow pupils to make those changes.

Each exercise gives the recommended voltage for that particular circuit.



Teacher's notes

Using this course:
It is expected that the worksheets are printed / photocopied, preferably in colour, for the pupils' use.
Pupils do not need their own permanent copy.

Each worksheet has:

- an introduction to the topic under investigation;
- step-by-step instructions for the investigation that follows;
- a section headed 'So What', which aims to collate and summarise the results, and offer some extension work. It aims to encourage development of ideas, through collaboration with partners and with the teacher.
- a section headed 'For Your Records', which can be copied and completed in pupils' exercise books. Alternatively, the 'Student Handout' can be photocopied and distributed to the pupils. This is a compilation of the 'For Your Records' sections.
  The idea is to save time by presenting the pupils with the body of the summaries, which they complete as they carry out the investigations on the worksheets.

This format encourages self-study, with pupils working at a rate that suits their ability. It is for the teacher to monitor that pupils' understanding is keeping pace with their progress through the worksheets. One way to do this is to 'sign off' each worksheet, as a pupil completes it, and in the process have a brief chat with the pupil to assess their grasp of the ideas involved in the exercises it contains.

"...but I'm really a biology teacher..."

Knowing that multidisciplinary integrated science teaching teams are increasing in popularity, the Teacher Guide is written with the intention of helping those teachers for whom physics is not their principal qualification or area of experience. It includes anecdotes and analogies to help deliver the concepts, and advice about pitfalls and misconceptions that may be present.

Time:
It will take pupils about five and a half hours to complete the worksheets. It is expected that a similar length of time will be needed to support the learning that takes place as a result.

Teacher's notes

Work-sheet	Notes for the Teacher	Timing
1	Introductory brainstorming/discussion/trigger questions could cover: What is electricity? Where does electricity come from? What do we use it for? The aim of the first exercise is to introduce the two classes of substance—conductors and insulators. First of all, though, the pupils set up a simple circuit to light a bulb. This gives them experience of using the kit, and ensures that the components all work properly! They then test a range of materials to see which category they belong to, by clamping each sample under the screw terminals of the sampler. If the bulb lights, the sample is deemed to be a conductor! The exercise points pupils towards the fact that metals conduct electricity well, whereas most other classes of substance do not. Most importantly, air is an insulator (though the teacher might raise the issue of lightning!) They are asked to devise a means for testing water. In reality, the result depends on the purity of the water used. This could form part of a class discussion on appropriate test methods. It may be appropriate to pick out the result that some substances conduct better than others. The present day electronics industry is built around materials called semiconductors, that are neither conductors nor insulators under normal conditions. Implicitly, the exercise also shows that an electric current flows only when there is a complete circuit. This topic is covered in more detail in the next worksheet.	30 - 45 minutes
2	It is worth comparing and contrasting a number of 'transport phenomena' - flow of water, flow of traffic, flow of people, flow of gas, with the flow of electricity. • Electrical circuits do not leak and do not 'burn' electrons. • Electrons do not park, don't crash and can't be squashed up. Electrical appliances convert electrical energy into a different energy form. That electrical energy is conveyed from the battery or the power supply to the appliance by electrons. They are rather like rail trucks, carrying coal or oil. Once they discharge their cargo, they return to pick up more energy from the power supply / battery. If a pupil questions the need for a complete circuit by saying that only one wire is needed to give an electric shock, contrast the case of birds that sit on high-voltage cables, with impunity provided their other leg is not touching the pylon! The dangers of creating a short-circuit are introduced, and should be reinforced by the teacher. It should never be possible to move round the circuit from one terminal of the power source to the other without passing through a component such as a bulb. On a practical level, batteries that are short-circuited go flat very quickly, and wastefully. The power supply alternative is current-limited, and will simply switch off if short-circuited. More important is the result that electric currents warm up the wires they flow through, and a short-circuit can warm them up so much that a fire can result. Electrical heating is the subject of the next worksheet.	20 - 30 minutes

Teacher's notes

Worksheet	Notes for the Teacher	Timing
3	We cannot see the current of electrons flowing around a circuit. We know it is there by the effects it creates. One of these is the heating effect. As electrons 'brush' past the positive ions in a wire, they cause them to vibrate a little bit more. We see this as an increase in temperature. Pupils could be asked to list all the electrical appliances that use this heating effect. The wire wool experiment should produce sufficient heat to make the strands glow, (and possibly snap,) allowing the comparison with filament lamps. (Use a piece of damp paper or cardboard to protect the baseboard from molten metal.) If this does not happen, the pupil has clamped too many strands between the posts of the sampler. The effect gives rise to the use of fuses, studied in worksheet 7.	20 - 30 minutes
4	A most important effect of electrons flowing is the magnetic effect they produce. A whole range of appliances use electromagnetism, as motors, transformers and solenoids. The magnetic effect is very weak, unless intensified by wrapping many strands of wire into a coil, or by then inserting a core of a magnetic material such as iron, to that coil. The pupils are invited to find a difference in the behaviour of iron and steel in this context. This is a pretty severe challenge using this equipment, but some may find that the steel nail retains its magnetism after removal from the coil, whereas the iron nail does not. The pupils may be allowed to wind their own coils, or this may be done earlier for them. Whichever method is used, there should be sufficient wire left out of the coil (~5cm) at each end to allow it to be clamped under one of the screw terminals of the sampler. Although not obvious, a thin layer of insulating lacquer covers the fine copper wire. Essential for the coil itself, this must be removed from the last cm. or so of the two ends to allow an electrical connection to the sampler. One way to do this is to burn it off, with a match, or to rub it off with a piece of sandpaper.	25 - 40 minutes
5	Another important effect of electricity is the chemical reactions it can produce. The one shown here uses the Locktronics baseboard only to hold the batteries or power supply connector. As it involves a liquid, and as copper sulphate, whether solid crystals or in solution is harmful if swallowed, the teacher may decide to carry out this experiment as a demonstration. It can be set up at the beginning of a lesson, and the results examined towards the end. It requires 200ml of aqueous copper(II) sulphate, at about 0.5 mol dm^{-3} At this concentration, the copper(II) sulphate solution is a low hazard. If the concentrations are increased, the solutions must be labelled with the correct hazard warnings. Copper(II) sulphate solution is harmful if concentration is more than 1M. (Refer to CLEAPSS Hazcard 27C) The electrodes can be either strips of copper foil, in which case one ends up really bright, because of the new copper deposited on it, while the other disintegrates, or graphite rods, in which case one becomes coated with copper, and looks pink as a result. You can use a graphite rod as one electrode and copper foil as the other, in which case connect the copper to the positive terminal of the power supply. Then you should see both the deposit on the graphite, and the eventual disintegration of the foil.	25 - 40 minutes

Teacher's notes

Worksheet	Notes for the Teacher	Timing
6	The use of a switch is investigated. The structure is examined to show that in the 'off' position, a layer of air prevents an electric current. The pupil is encouraged to try different configurations to control one or two lamps. There is a large number of switch types available. Two broad categories are introduced, the 'push' switch (or momentary acting switch,) and the toggle (or latching) switch. Pupils could be set the task of researching other types of switch, and applications in which they could be used.	20 - 30 minutes
7	We return to the heating effect of an electric current, and, in particular, its use in fuses. A fuse is the weakest link in the circuit. If anything melts, it is the fuse. In the process, a layer of insulating air is placed in the circuit and the current stops. The fuse is a device for preventing fires, and for protecting electrical equipment, not a means of preventing electric shock. The human body has such a high resistance that, when touching a high voltage wire, a very small current flows - sufficient to cause serious injury, but insufficient to 'blow' the fuse. Devices such as the earth wire, and RCCBs provide protection against electric shock. The instructions ask the pupil to touch the flying lead momentarily across the lamp to cause a short-circuit. If the steel wool 'fuse' does not melt as a result, then probably the pupil has clamped too many strands between the posts of the sampler. (Use a piece of damp paper or cardboard to protect the baseboard from molten metal.)	20 - 30 minutes
8	Here we examine the use of circuit symbols as an efficient way of describing the structure of a circuit. As an introduction, pupils could be shown, or could find for themselves, a number of common non-electrical symbols, such as road signs, to demonstrate that these pictorial messages are quick and easy to understand. They should be encouraged to learn the basic symbols, and research a range of others. The pupils are then asked to build, and comment on six circuits, as practice in interpreting circuit diagrams. They should be reminded to select the correct power supply voltage for each. The circuits also show, again, the effect of placing a switch in different positions in the circuit.	30 - 45 minutes
9	The concept of resistance is central to understanding electrical circuits. Comparison should be drawn to the effect of narrow pipes in a water circuit (which cut down the flow everywhere in the circuit,) and road works on a motorway, which soon lead to reduced traffic flow over whole sections of the motorway. The experiments are still using the brightness of a bulb as a measure of the size of current flowing. Using two lamps in series, i.e. adding resistance, is seen to reduce the current. The pupils make their own resistor from a length of graphite rod, and look at its effect. This rod needs to be fine for the effect to be noticeable! The ohm is mentioned as the unit of resistance, and pupils connect a fixed resistor into their circuit, to compare the effect. The topic of resistance will be developed much further in the next course.	20 - 30 minutes

Teacher's notes

Worksheet	Notes for the Teacher	Timing
10	Another important idea—series and parallel connections! Linked to this is the notion that electrons favour the easiest route around a circuit. Once again, the brightness of a bulb is used as a measure of electric current. Some pupils start with an erroneous belief that the current should get smaller as it flows around the circuit. This is true for a gas flow system, where a number of burners are fed from a common supply pipe. Each burner burns a certain volume of gas each minute, leaving a smaller flow down the pipe to the next burner. The similar brightness of all bulbs in a series circuit is used to dispel this idea. Series circuits offer only one route, and so if a break occurs in that circuit, such as a faulty bulb, or 'blown' fuse, then no current can flow. A parallel circuit offers alternative routes. Pupils should be encouraged to trace out all possible routes, and to assess which of them is easiest from the electron's perspective. That route we expect to carry the highest current. In terms of traffic flow, parallel routes are often called bypasses, and are built to increase traffic flow either by avoiding features such as narrow bridges, or simply by having two roads to carry the traffic. Teachers should refer to local examples of these, where possible. The exercises give further practice in recognising series and parallel connections, and in making deductions about the currents flowing in them.	25 - 40 minutes
Quiz	This is included as one means of assessing a pupil's grasp of the topics covered in the worksheets. This can be run as a conventional test, answered by each pupil individually, or can be organised as a 'pub' quiz for the whole class, where the teacher splits the pupils into teams. The questions could be printed out for the teams, or could be projected onto a screen with a data projector.	20 - 30 minutes

Student handout

Worksheet 1

- Most of the conductors belong to the class of substances called ....
- I think that the hard shiny object that felt cold would .... electricity, because it is probably made of a ....
- Pure water is an .... However, if there are any impurities in it, such as salt, or chlorine, then the water is a ....
- Air is an .... which explains why we do not get an electric shock when we stand near a mains electricity socket.

Worksheet 2

For a bulb to light, there must be:

- a source of ...., such as a battery or power supply;
- wires of metal to .... the electricity;
- wires which are insulated by a .... coating to stop the metal conductors touching each other;
- a complete ...., with no gaps in it.

Worksheet 3

- When an electric .... flows through wires, it warms them up.
- Some kinds of wire get so hot that they ....
- One kind of light bulb, called a filament lamp, uses this effect to produce light.
- They are expensive to run because they give off more .... than ....

Worksheet 4

- When an electric current flows through a wire, it produces a .... effect.
- The effect is stronger if you form the wire into a coil and push a nail, made of .... or ...., down the centre.
- The nail then behaves like a .... It affects a compass needle, and can even pick up paper clips.
- Two ways to make the magnetic effect stronger are:
    - add more ....;
    - increase the ....

Worksheet 5

Fill in the gaps with either 'positive' or 'negative'.

- During the experiment with copper sulphate solution, the .... electrode gets coated with copper and gas bubbles are given off at the .... electrode. We know that an electric current is flowing through the solution because ....

Fill in the gaps with either ''electrolysis' or 'electroplating'.

- In .... an electric current causes a chemical reaction that splits compounds into simpler molecules. It is used to obtain pure elements, such as copper, aluminium and chlorine from their ores or from commonly occurring compounds.
- .... is one example of .... where the aim is to coat one metal with a thin layer of another to protect the underlying metal from corrosion or wear (e.g. chrome plating on automotive parts), or to enhance its appearance (e.g. gold plating.)

Student handout

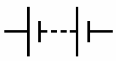
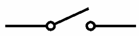
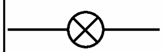
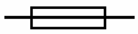
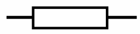
Worksheet 6

- A switch starts and stops the flow of ....
- When the switch is open, the .... gap stops the flow of electricity.
- When the switch is ...., the air gap disappears, and electricity flows around the circuit.
- A toggle switch stays on or stays off all the time. A push switch is on only as long as you press it.
- A doorbell is one type of .... switch.
- A light switch is one type of .... switch.

Worksheet 7

- A fuse contains a fine metal wire. When the flow of electricity gets too big, this metal gets so hot that it ...., and breaks. This creates an air .... in the circuit, which stops the flow of electricity.
- This stops the other .... in the circuit from getting too hot, and causing a fire.

Worksheet 8

					
Battery	**Toggle switch**	**Lamp**	**Fuse**	**Resistor**	**Sounder**
Supplies electrical energy	**Allows a circuit to work**	**Turns electricity into light**	**A safety device**	**Controls the size of the current**	**Turns electricity into sound**

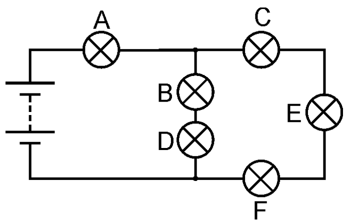
Worksheet 9

- A resistor limits the flow of electricity
- The bigger the resistance, the smaller the electric current.
- Resistance is measured in ohms. Usually, we use the Ω sign to mean 'ohms'.

Worksheet 10

- A series circuit offers only one route for the electric current.
- If a break appears anywhere in the circuit, then the electric current stops everywhere.
- If one bulb fails in the circuit, then all the bulbs go out.
- The electric current is the same size throughout the circuit.
- A parallel circuit offers more than one route and so different currents can flow in different parts of the circuit.

1. Bulb B is in series with bulb ....
2. Bulb C is in .... with bulb E and bulb F.
3. Bulbs B and D are in .... with bulbs C, E and F.
4. The biggest current will flow through bulb ....



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Date	Release notes	Release version
2010	First version released	LK7325-80-1 revision 1
20 03 2012	Many changes to worksheets and LK9070 kit	LK9893-80-1 rev 2
15 01 2015	Minor change to LK9071 partlist	LK7325-80-3
03 08 2016	Students notes - worksheet 5 minor changes	LK7325-80-3
15 08 2023	Reformatted to new style	