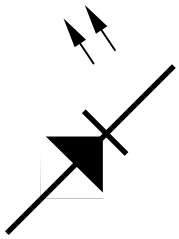
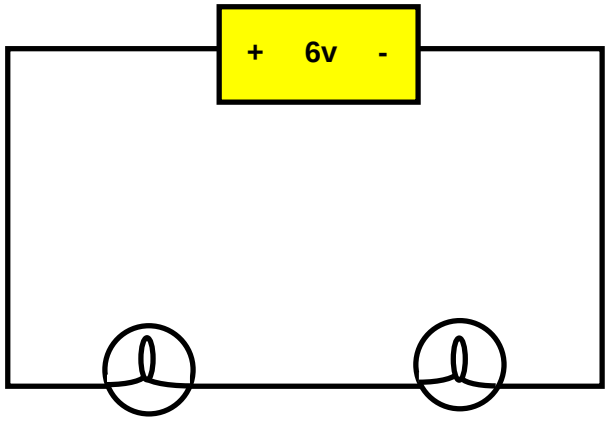




BUZZER

LAMP

RELAY

APS
BASIC ELECTRICITY
TEACHING BOARDS

LED

SWITCH

PARALLEL

CIRCUIT DIAGRAM

TEACHER'S GUIDE

SERIES

INSULATOR

BATTERY

CIRCUIT SYMBOL

SHORT CIRCUIT

CONDUCTOR

VOLTAGE

ELECTROSOUND 01376 340506

Introduction

The **APS BASIC ELECTRICITY MODULES** are designed to introduce pupils to electricity in an easy to use format. All connections are made using crocodile clip leads. The system is designed to negate the problems which arise from a box of assorted electrical "bits" which need to be sorted/repaired before each lesson.

Apart from the boards, the only other equipment required will be a source of power. The boards are designed to be run from a 6V d.c. source. This may be 4 x C or D cells in a holder, a PJ996 lantern battery, Nickel Cadmium rechargeable cells (5 off) or a suitable low voltage power supply unit (see appendix for details).

The list of experiments is by no means exhaustive but should serve to form a solid basis for a teaching scheme.

For those teachers who have little or no experience in the teaching of electricity, I strongly recommend that you work through the experiments yourself prior to presenting them to the pupils.

Each experiment in this guide is accompanied by a possible (but not necessarily the only) wiring solution and a series of questions. As such, the experiment sheets should not simply be photocopied and placed in front of the pupils, but rather be used by the teacher as the basis for their lessons.

In all the experiments the following conventions are used:

+ the positive side of the battery or red terminal of the low voltage power supply

- the negative side of the battery or black terminal of the low voltage power supply

For simplicity, the power source will be referred to as a battery throughout the booklet.

After the experiment title, the number(s) in brackets indicates the circuit board(s) to be used.

The board diagrams in the appendix may be freely photocopied and offer a simple way for the pupils to records their circuit layouts.

Before each lesson, it is advisable to check that the lamps are firmly screwed into their holders. Replacement lamps are 6V, 60mA MES type.

Should you experience difficulties or require additional information about any of the experiments, please do not hesitate to telephone me.

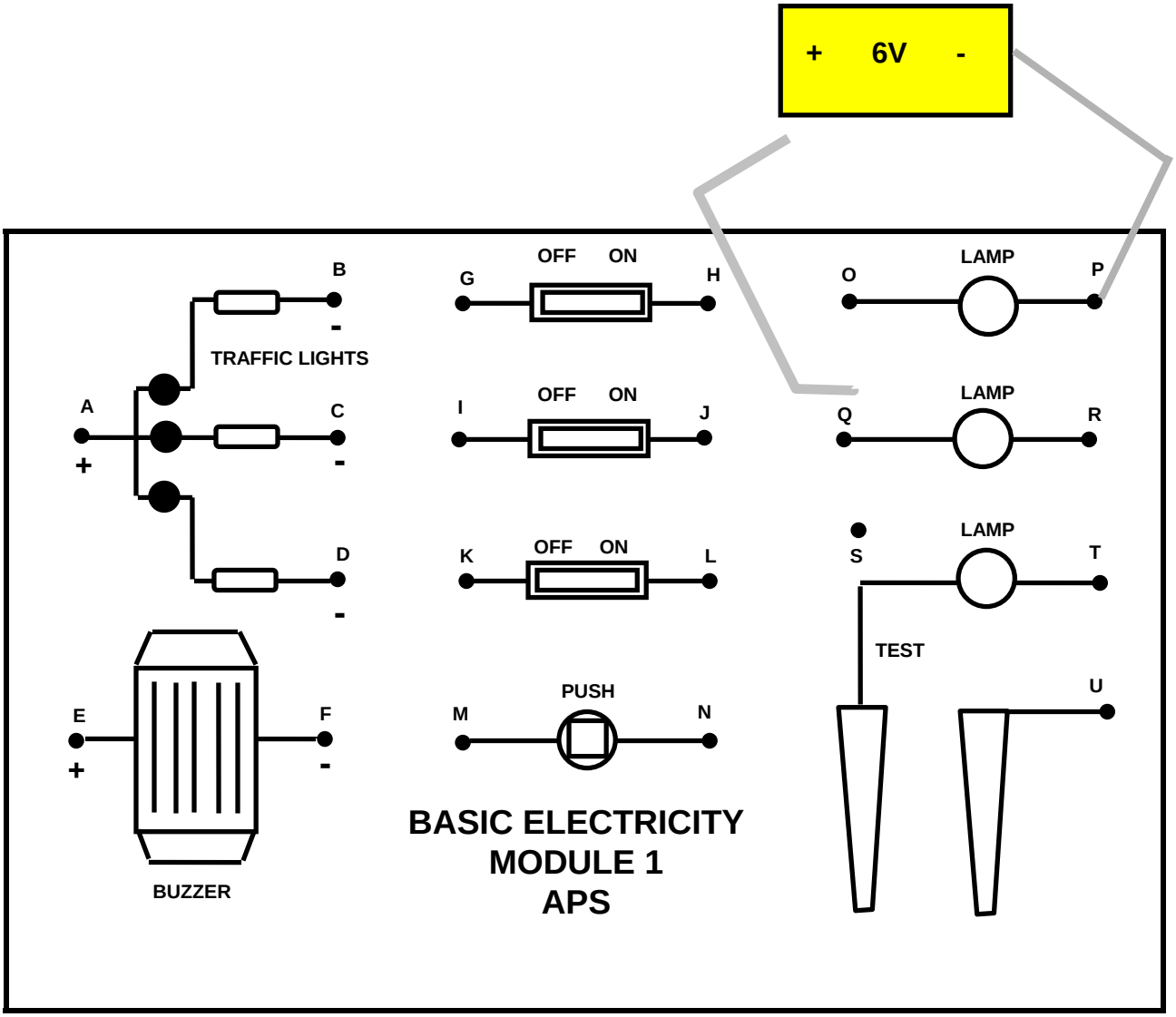
Phil Walsh
ELECTROSOUND
01376 340506

Experiment 1. Lighting a Lamp (1)

Using the battery and two leads, try to light a lamp.

On a copy of the circuit board, draw in your connections. Show the battery as a box.

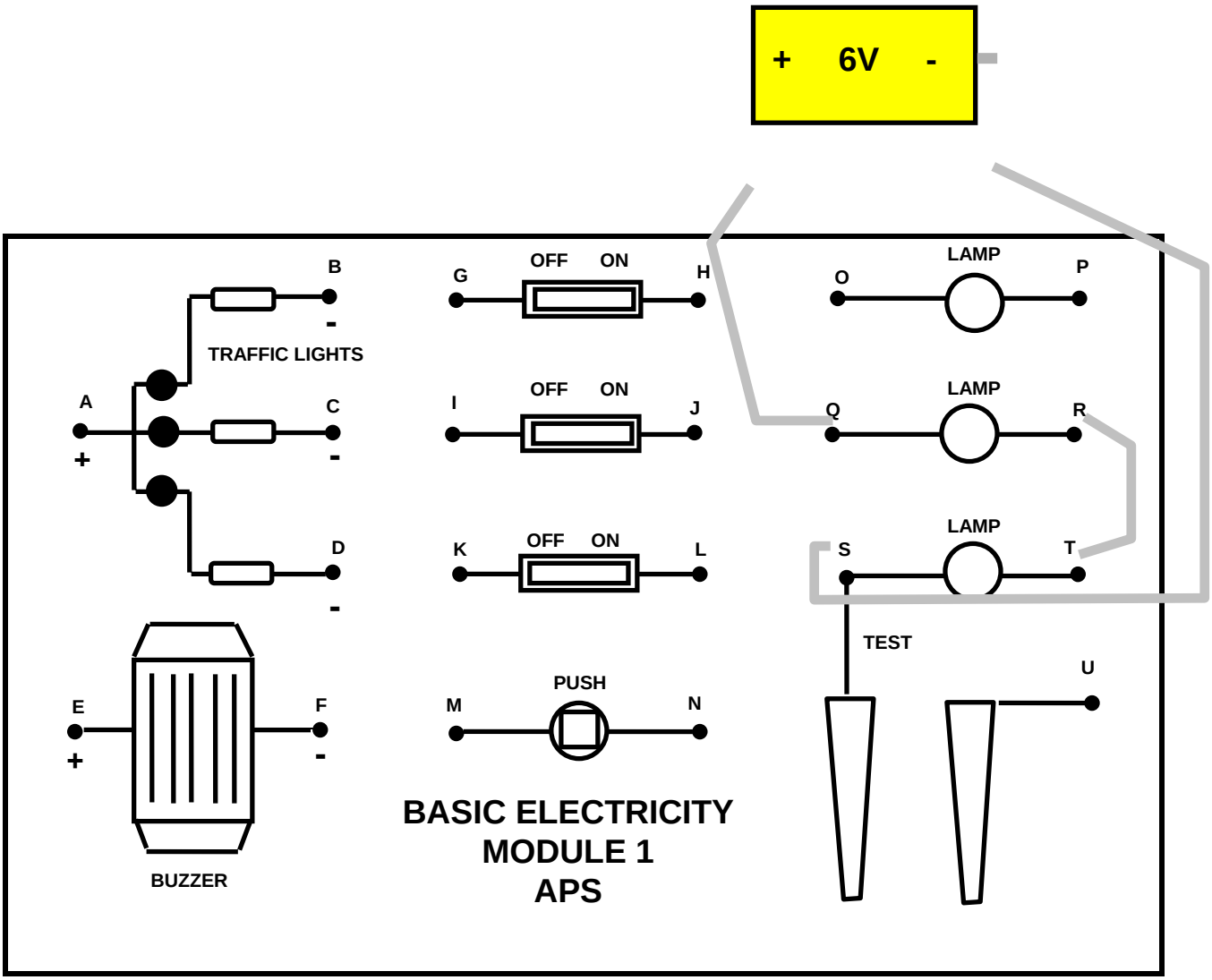
e.g.



N.B. If a battery pack or low voltage power unit (e.g. The Spider from Electrosound) which can supply 1.5V, 3V, 4.5V and 6V is available, Experiment 1 should be extended to show the brightness of the lamp at the difference voltages. This can be used as reference data in Experiment 2.

Experiment 2. Lighting 2 and 3 lamps (1)

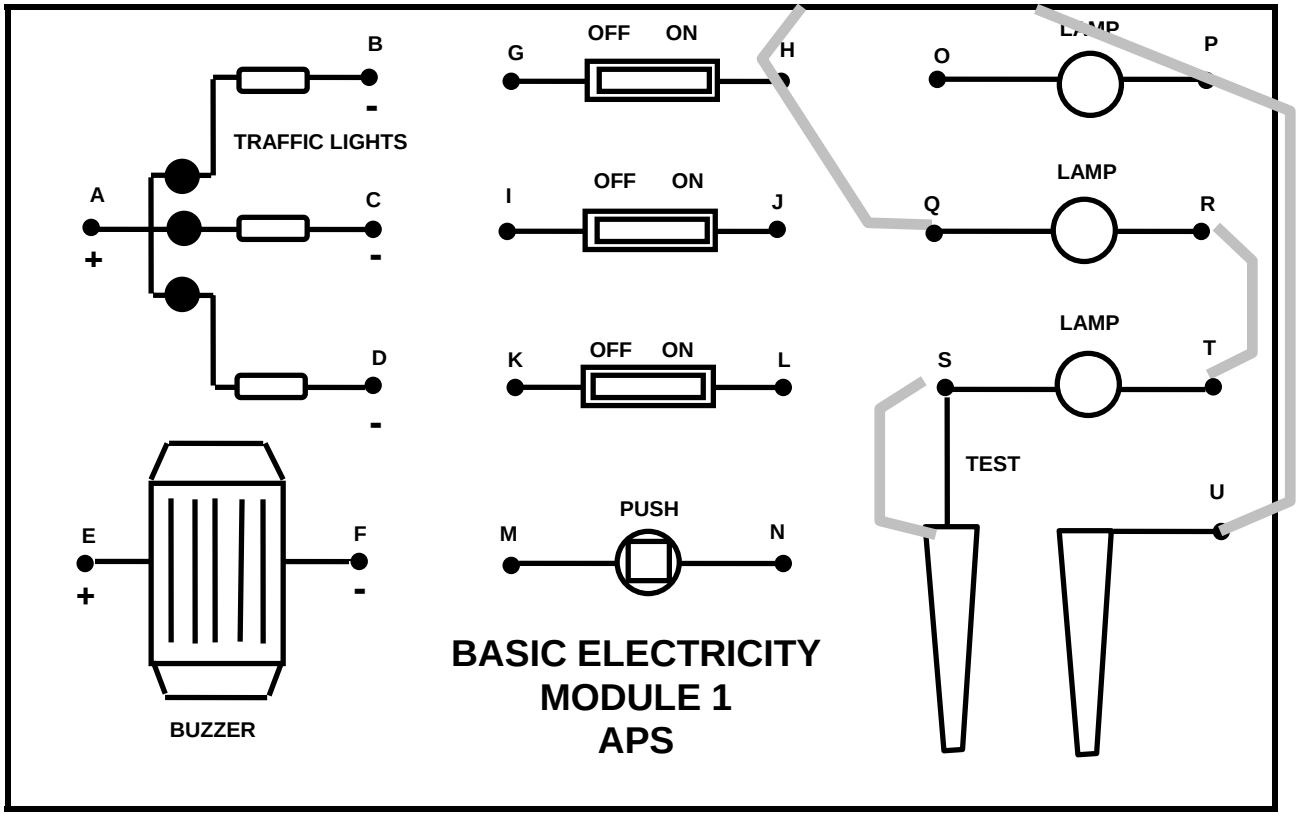
Try to light 2 lamps using only 3 leads.



Write about the brightness of the 2 lamps compared to the single lamp in Experiment 1.

Now try to light all three lamps using only 4 leads.

+ 6V -



Write about the brightness of the 3 lamps compared to 1 and 2 lamps.

Carefully unscrew one of the lamps. What happens?

Screw the lamp back and unscrew another. What happens?

With all the lamps glowing, unclip one end of a lead from one of the terminals on the board. What happens? Does it matter which lead you unclip?

With all the lamps glowing swap over the two leads on the battery. Does this make any difference?

The sort of wiring used in this experiment is called SERIES wiring. In SERIES wiring, the electricity goes through the lamps one at a time.

Cross out the wrong words in the brackets:

The more lamps you wire in series, the (dimmer/brighter) the lamps are. If there is a break anywhere in the circuit all the lamps (get brighter/go out).

Christmas tree lights are wired in **SERIES**.
The reason the lamps are not at full brightness in a series circuit is because they share the voltage from the battery between them. The battery supplied 6 volts. Try to fill in the table below:

Voltage across each lamp	Number of lamps
6V	1
	2
	3
1V	6

Do you think 6 lamps in series will glow bright enough to see?

If two groups use their boards together, you can try it out.

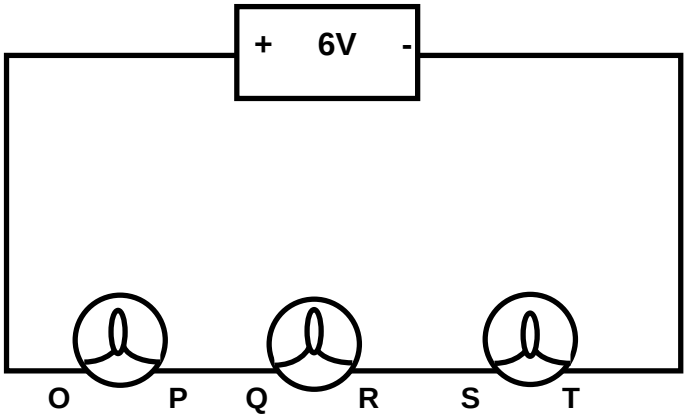
Try 4, 5 and 6 lamps (use only one 6V battery).

Fill in the table below:

Brightness	Number of lamps
Very bright	1
	2
	3
	4
	5
	6

Experiment 3. Short Circuits (1)

When something (like a lamp) is wired to a battery and is glowing, we call the whole thing a complete circuit. Below is a circuit with three lamps wired in series. You can see that it is drawn in a box shape to straighten out the wires and make it look neat.



Circuit Symbols

To make drawing quick, a lamp is drawn like this:

This is called a circuit symbol.

This is the **circuit diagram** of Experiment 2. The terminal letters from the board are shown. Make the circuit on the board and check that the wires go to the correct places.

A short circuit is a link, which causes the electricity to bypass one or more lamps.

With another wire, link terminals Q and R - this short circuits the middle lamp.

What happens to the middle lamp?

What happens to the other two lamps?

Remove the link from terminal R and clip it to terminal T.

What happens now?

What do you think the voltage across lamp O-P is?

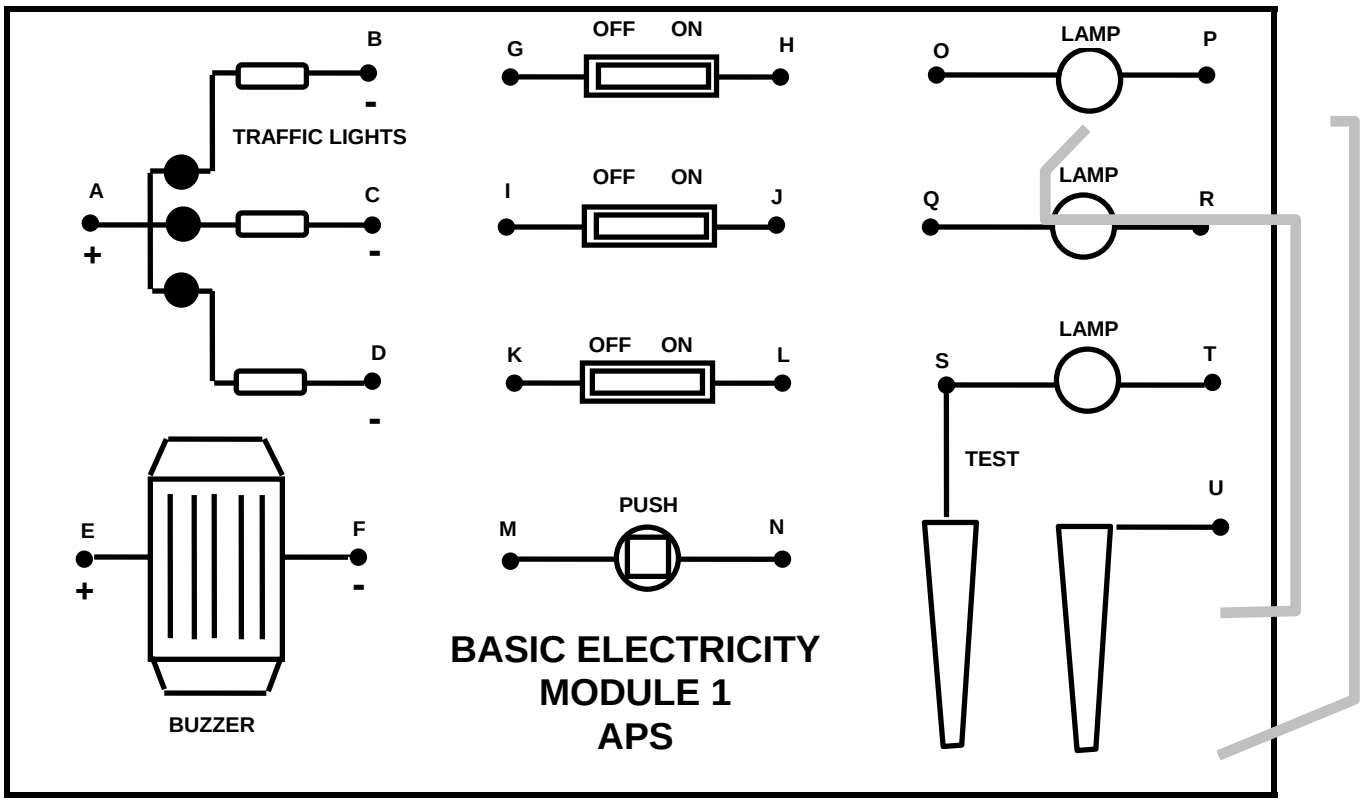
SHORT CIRCUITS ACROSS THE BATTERY TERMINALS CAN QUICKLY RUN IT DOWN. TRY TO AVOID THIS TYPE OF SHORT CIRCUIT.

Experiment 4. Electrical Conduction (1)

To make a circuit work, the electricity must flow out of the + side of the battery, through a component such as a lamp, and back to the - side of the battery: this is called a **CIRCUIT.**

This experiment investigates what materials allow electricity to easily flow through them - they are called **GOOD CONDUCTORS .**

+ 6V -



Connect two leads from the battery to the board as shown.

Touch another lead between terminals T and U and check that the lamp lights.

Now test different materials by bridging them across the two crocodile clips. If the lamp lights then the material is a **GOOD CONDUCTOR;** if it does not light, the material is a **POOR CONDUCTOR** or **INSULATOR.** Make a chart like the one below:

Material	Conductor	Insulator
Paper	✗	✓

When there is nothing between the crocodile clips, the lamp does not light. Is there really nothing between the crocodile clips? (Hint: What are the clips screwed to? What are you breathing?)

You should now be able to add two more things to your chart (if you hadn't already thought of them!)

On your chart, put a ring around all the things that are made of metal.

Generally, **METALS ARE GOOD CONDUCTORS AND NON-METALS ARE INSULATORS.**

Experiment 5. Switches (1)

A switch is made of insulators and conductors and is wired in series with a lamp. When the switch is open (off), the conductors are moved apart to give an insulating air gap. When the switch is closed (on), the conductors move to touch each other.

Build the circuit from Experiment 2 with all three lamps. Now, using one more lead, change the wiring so that switch G-H is in series with the lamps. Moving the switch from OFF to ON should cause all the lamps to light.

Does it matter where in the series circuit you place the switch?

Now use switch M-N instead. This switch works in a different way.

Switch G-H is called a **SLIDE SWITCH** and switch M-N is a **PUSH SWITCH**.

Which type of switch would you use for a doorbell? Why?

Try it out by wiring a switch and the buzzer in series. It is important to wire the + of the battery to the + of the buzzer.

Try wiring the buzzer the wrong way round and you will see that it does not work.

Experiment 6. The Direction of Electrical Flow (1)

In the last experiment, it was important to wire the buzzer the correct way round. This is because electricity flows in one direction around the circuit (from + to -). Lamps and switches will work when the electricity flows in either direction but some components will only work properly when the electricity flows in the correct direction.

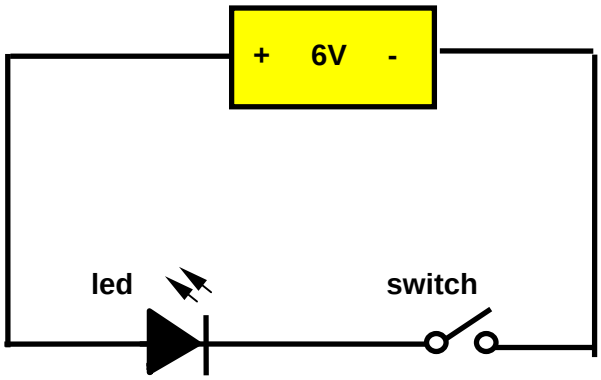
Another component which only works in one direction (we say it is POLARISED) is a **LIGHT EMITTING DIODE**. This is known as a **LED** for short.

The board has three leds on it arranged like traffic lights. Look carefully at the board. You will see that one side of each of the three leds is connected together. This is done so that you do not have to use so many leads.

Wire led A-B to the battery through switch G-H. Make sure you connect the + of the battery to the + terminal of the leds (terminal A). You will need three leads.

You should be able to switch the red led on and off using the switch.

The circuit diagram for this is shown below. You will notice that two more circuit symbols have been introduced.



The symbol for the led is a large arrow with a bar at one end and small arrows coming out. The large arrow shows the direction the electricity flows through it, the bar shows the direction that blocks the electricity and the small arrows show that it gives out light.

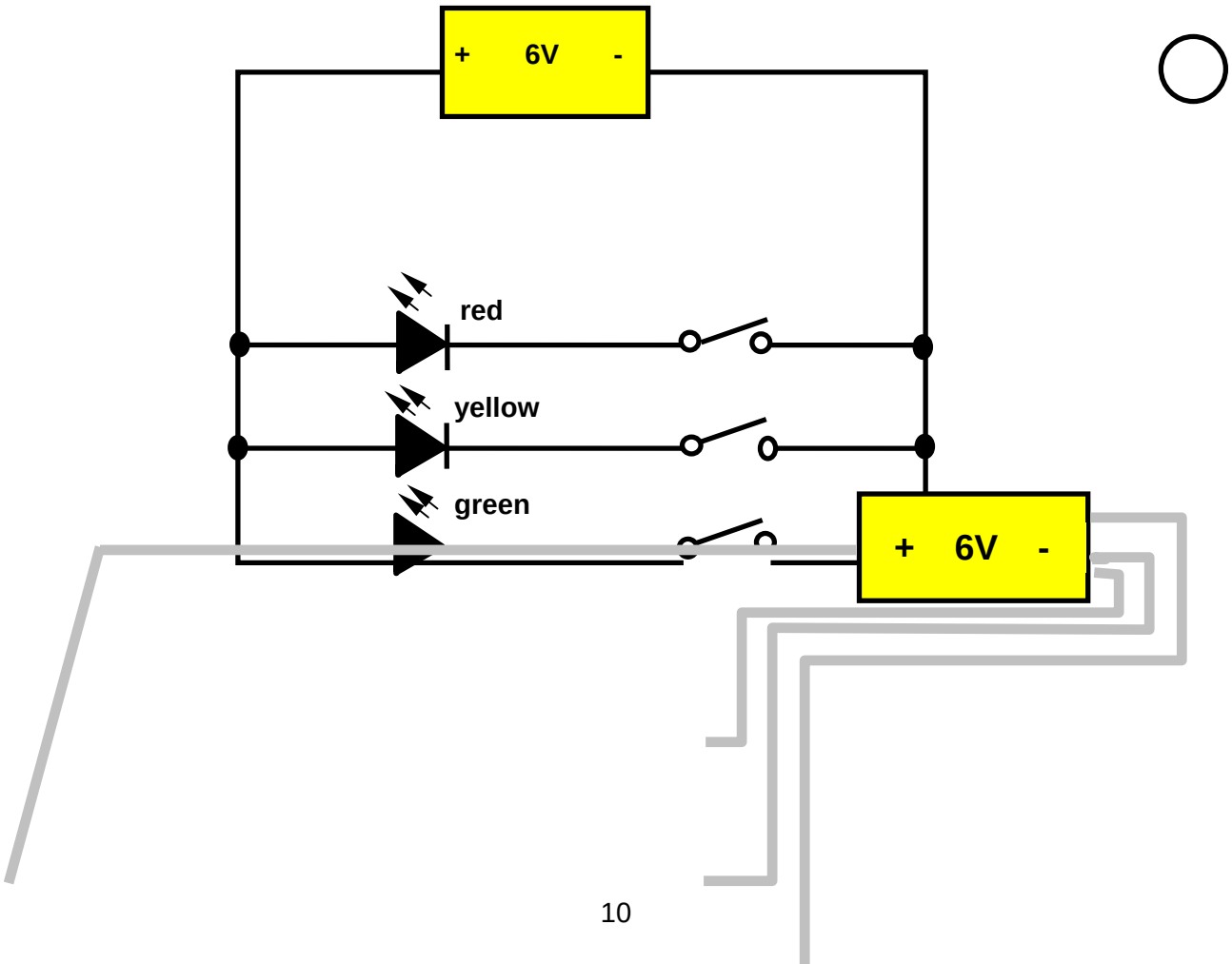
Using two more leads, connect the yellow led to switch I-J and link the other side of the switch back to the battery terminal.

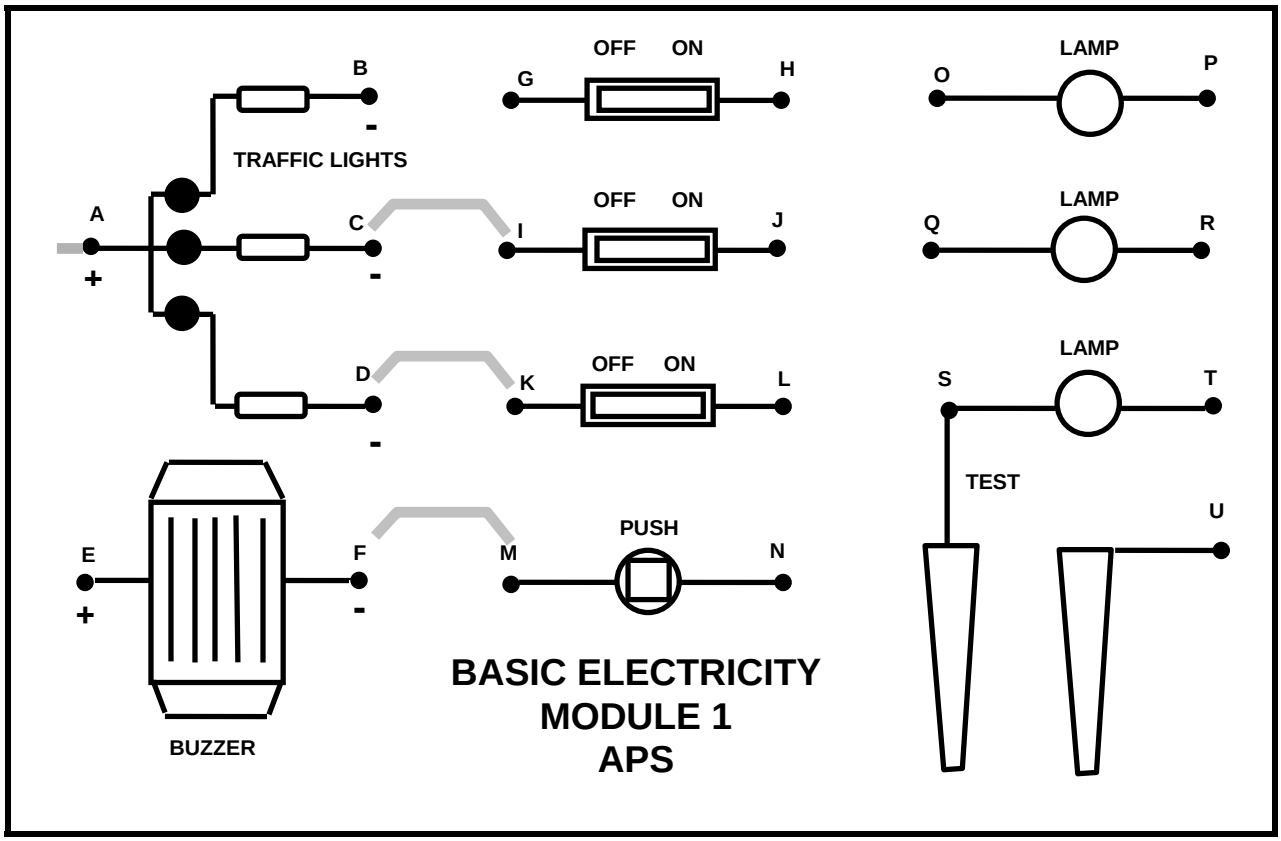
You should now be able to switch the red and yellow leds on and off separately.

Using two more leads, see if you can switch the green led on and off as well.

Find out the order in which traffic lights change and, using the three slide switches, try to make the three leds work like traffic lights.

The circuit diagram and a board layout for this very complicated circuit are shown below.



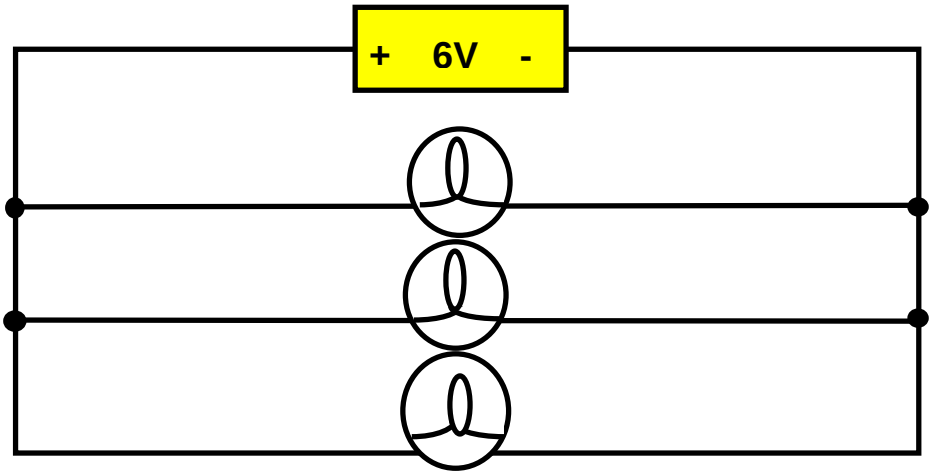


If you compare the circuit diagram with the picture of the board above, you will see that the wires from the switches to the - terminal of the battery are taken separately to the battery. The diagram shows them linked together and the wire is taken to the battery. It does not matter which way you wire it as long as all the terminals (H, J and L) are connected together and also connected to the battery terminal.

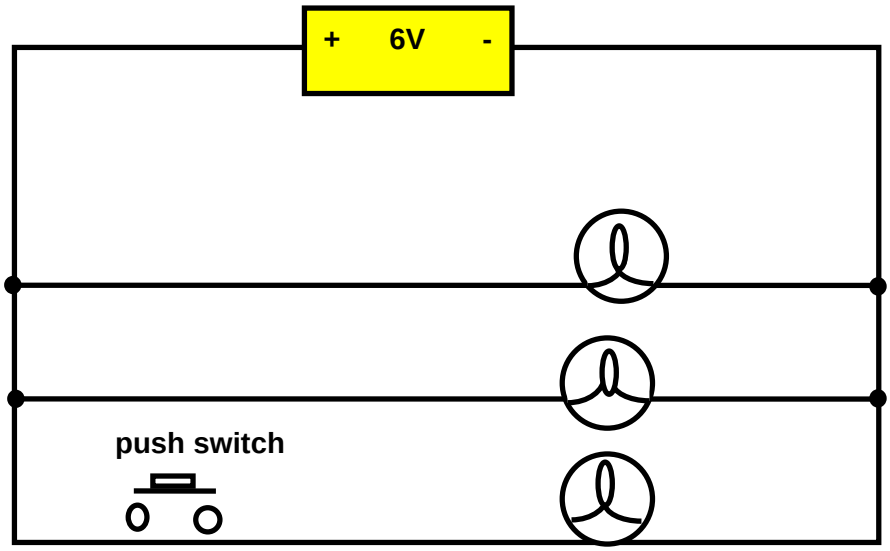
Experiment 7. Parallel Circuits (1)

The leds in experiment 6 were not wired in series. Each led was wired, through a switch, to the battery. If you trace from the + battery terminal to the red led, through the switch and back to the

battery, you will see that this forms a complete circuit. Now trace the yellow led circuit and then the green led circuit. The traffic lights circuit is, in fact, three separate complete circuits. The three circuits may share some leads, but they are all independent. The whole thing is called a **PARALLEL** circuit.



Wire up the circuit shown above. This is three lamps wired in PARALLEL. What do you notice about the lamp brightness? What happens when you unscrew one lamp? What happens if you unscrew two lamps? Screw the lamps back in so that they all light. Unclip the lead from lamp terminal S. The bottom lamp should go out. If we put a switch here, we can switch the bottom lamp on and off without affecting the other two lamps. Try to wire push switch M-N into the circuit to do this. You will need an extra lead. The circuit diagram for this is shown below.



You will notice a new circuit symbol. This is how we draw a push switch.

Difficult!

Leave the wiring as it is and, with an extra lead, see if you can get slide switch K-L to switch the middle lamp on and off without affecting the bottom lamp which should still operate from the push button even if slide switch K-L is off!

Even more difficult

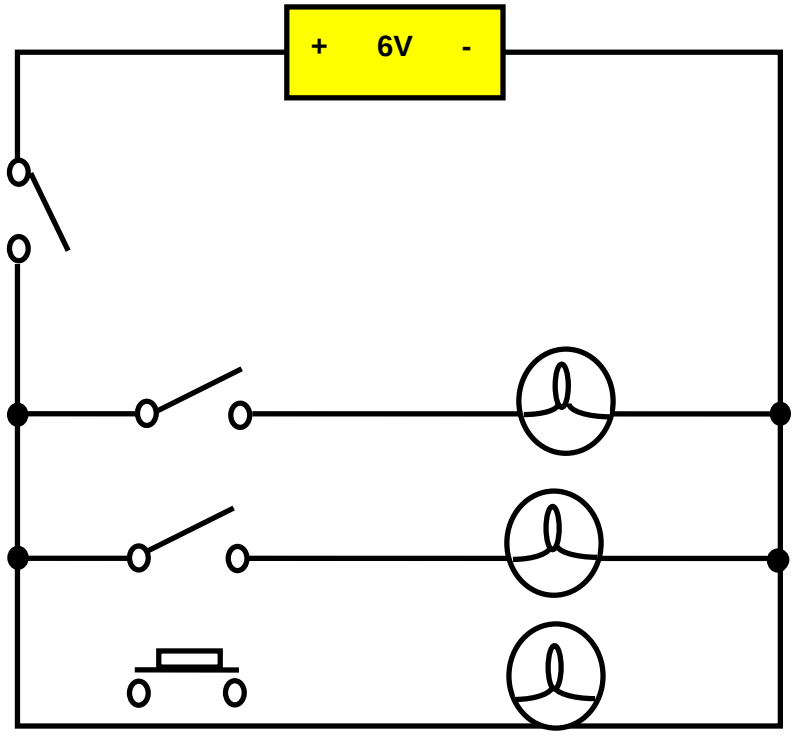
Now do the same with the top lamp and switch I-J (you will need another lead). Both the middle and bottom lamps should not be affected. Finally, disconnect the lead from the + of the battery and connect it to slide switch terminal H.

MAKE SURE THE SLIDE SWITCH IS OFF.

Connect another lead between slide switch terminal G and the battery + terminal.

DO NOT SWITCH G-H ON YET!

Look at the circuit diagram below and see if you can predict what switch G-H does. Hint: Switch G-H is in SERIES with the rest of the circuit.



Connect the battery and slide switch G-H on. Were you right? Congratulations! You have built a very complicated circuit using all 10 leads!

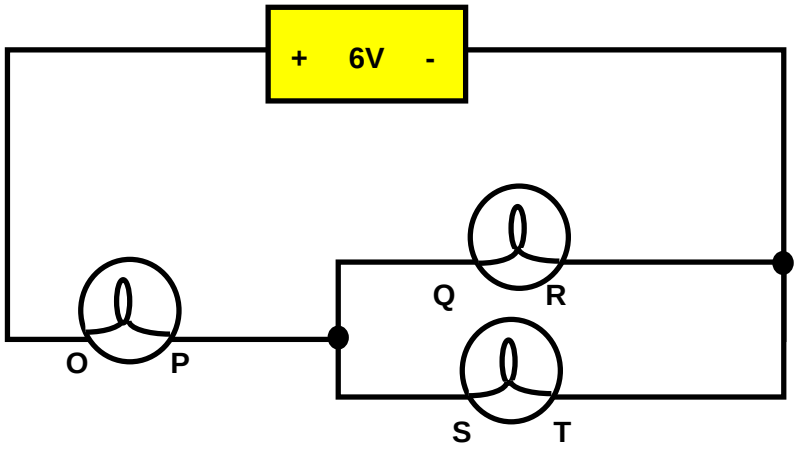
This type of circuit is like the one used in your home. For example, the top lamp could be the lounge, the middle one could be the kitchen and the bottom one could be a bedroom (although very few bedrooms have a push switch!)

If you swap the connections from the bottom lamp to the buzzer, you could add a doorbell to the circuit (remember to wire the buzzer the correct way round).

Is there a switch which works like G-H in your home?

Experiment 8. Series/Parallel Circuits (1)

The lamps in the last circuit all glowed with full brightness. This means that they are not sharing the voltage - they each have 6 volts across them. Unfortunately, you don't get something for nothing! The battery has to push more electricity around the circuit (3 times as much as for a single lamp). The amount of push (6 volts) is still the same but the amount of electrical stuff being pushed around the circuit (it is called CURRENT) is 3 times bigger. If you are using batteries, this means that they will run down 3 times quicker. If you are using a low voltage power supply, it means that you use 3 times as much electricity and your electricity bill will be 3 times bigger.



Look at the circuit diagram above. Lamps Q-R and S-T are in parallel with each other but lamp O-P is in series with both of them!

Try to answer the following questions without making the circuit:

What would happen if you unscrewed lamp O-P?

Which lamps will have the same brightness?

What would happen if you unscrewed lamp Q-R? What would be the voltage across lamp O-P now?

Questions

Draw a circuit diagram of one lamp being powered by a battery.

If a street lamp burns out the rest continue to glow. Are street lamps wired in series or parallel?

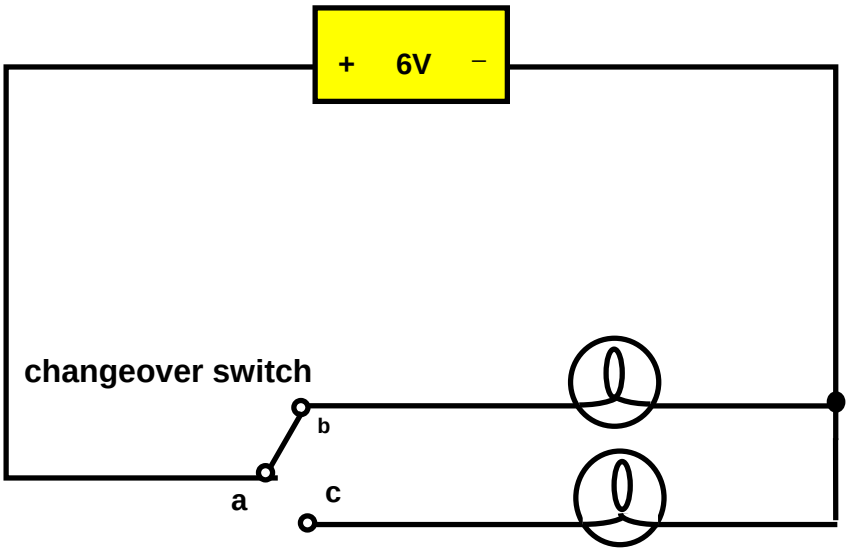
From the following list, write down those things which are good conductors:

glass, paper clip, rubber band, plastic cup, 10p piece.

The mains lead on an electric kettle has a plastic coating on it. Why do you think this is?

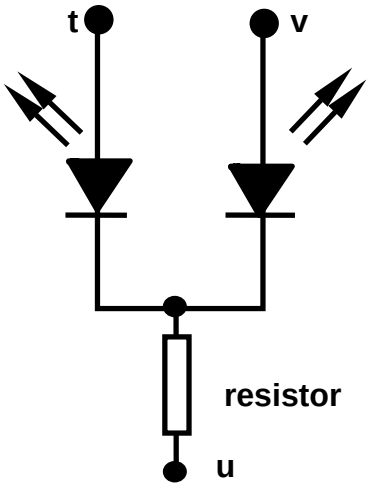
Experiment 9. The Changeover Switch (2)

When a normal switch is operated, it switches a single circuit on or off. The changeover switch goes one stage further.



Wire up the circuit shown above. When the switch is operated, it will switch one lamp on and the other off. There is always one lamp on at any one time.

We can also use the changeover switch with the tricolour led. This is two leds contained in one casing. They are wired like this:



The component with the coloured bands is called a RESISTOR. This is used because leds are designed to operate on 2 volts and we are using a 6 volt battery. The resistor acts like the second lamp in Experiment 2 - the voltage is shared between the led and the resistor, but not equally. The resistor takes the bigger share of the voltage (4 volts) leaving 2 volts for the led. If you look at the Module 1 board, you will see that each of the traffic light leds has its own resistor.

Connect the + of the battery to changeover switch terminal a. Connect terminal b to t and c to v. Finally connect terminal u to the - battery terminal.

What happens?

What happens when you operate the switch?

Draw a circuit diagram of your circuit.

Experiment 10. The Reed Switch (2)

The reed switch is operated by a magnet.

Connect the reed switch in a series circuit with lamp i-j and the battery. Now bring the magnet close to the reed switch.

What happens?

You can now switch a lamp on and off without touching anything!

Experiment 11. The Changeover Relay (2)

The changeover relay is a changeover switch that is operated by electricity.

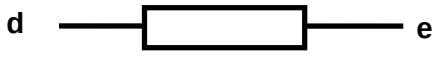
Clip leads to the coil terminals d and e and then clip them to the battery terminals - you should hear a click. You can switch the relay off and on again by unclipping one of the leads and then clipping it back again. If you look carefully at the relay, you should see the CONTACTS inside moving. This is the changeover switch. The centre contact is wired to terminal f. When the relay is off, f is connected to h (h is known as the Normally Closed [N/C] contact). When the relay coil is switched on, the connection between f and h is broken and f contacts g instead (g is known as the Normally Open [N/O] contact).

Look back at the circuit diagram in experiment 9. We can replace the changeover switch with the changeover relay.

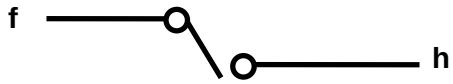
Build the circuit again but this time, use the relay contacts instead of the changeover switch. One lamp should light. If it doesn't, check your wiring. If you can't find a mistake, read the instructions in the box below.

> Connect the + battery terminal to terminal f. Connect terminal l to terminal g. Connect terminal k to terminal h. Connect terminals j and l and connect these to the battery - terminal.

If you connect the relay coil to the battery, the relay will operate and the lamp that is alight should change over.




g



The circuit symbol for a changeover relay is shown above.

Draw the circuit diagram of your new circuit.

Experiment 12. Bicolour and Tricolour Leds (2)

We used the tricolour led in experiment 9 and found that it glowed either red or green. Tricolour means three colour, so where is the third colour?

Experiment to see if you can get the red and green leds to light together (you should only need three leads).

Draw a circuit diagram and write down what the three colours are.

Like the tricolour led, the bicolour led is two leds in one casing (or package). Unlike the tricolour led, the bicolour led has only two connections.

Using only two leads, see if you can make two colours with it.

Experiment 13. Two way switching (1 and 2)

We previously looked at parallel wiring (experiment 7) and compared it with wiring in the home. There is one type of wiring found in the home that we did not look at - two way switching. This is the type of switching where one lamp can be switched on and off by two different switches (this is used for landing lights etc.)

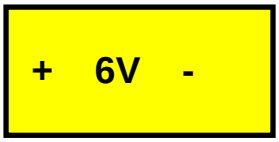
Using board 1, try to use two switches so that a lamp may be switched on and off by either of them. (Hint: Try wiring two switches in parallel and then putting them in series with a lamp. Then try putting two switches in series with each other and in series with a lamp.)

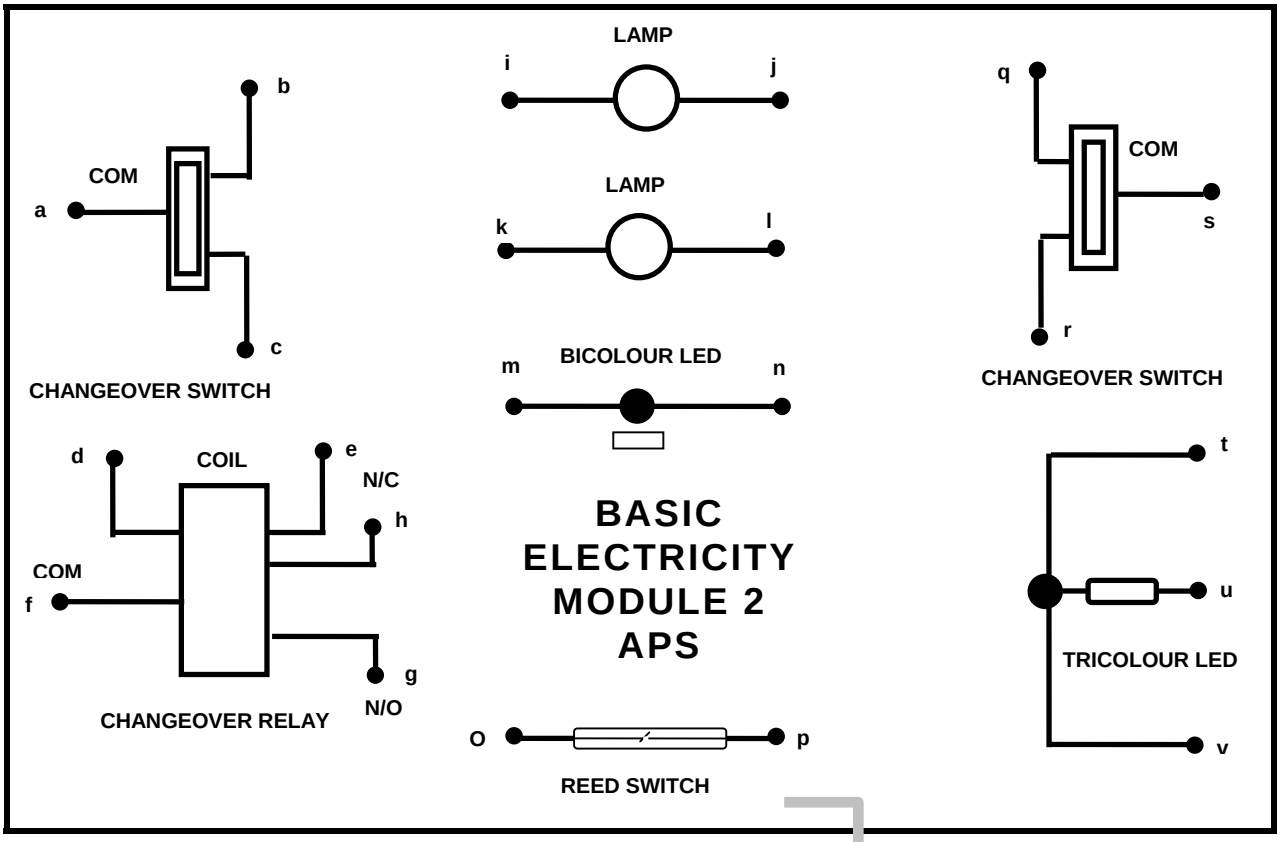
Draw circuit diagrams and write about what happens with each circuit.

Is it possible to switch the lamp on with one switch and off with the other?

Does it work all the time?

Unfortunately, you cannot get it right using standard switches - for this you will need changeover switches (they are sometimes called two way switches).

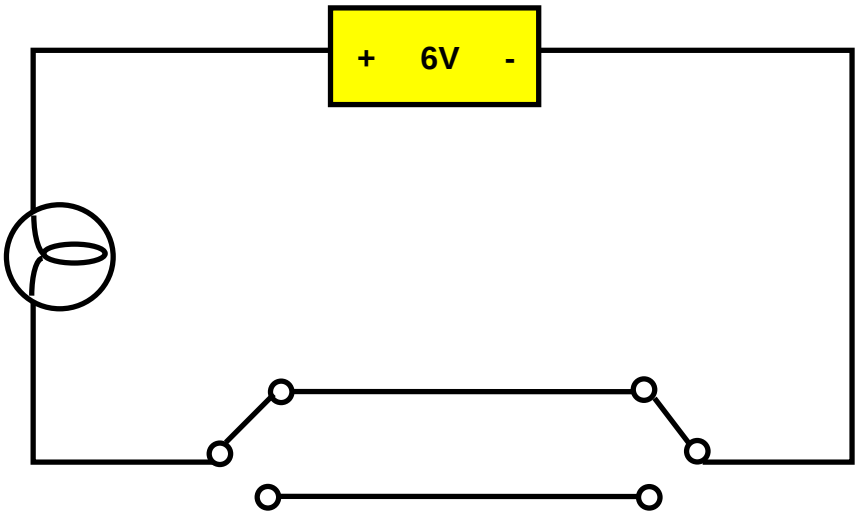




Using Board 2, carefully wire up the circuit shown above.

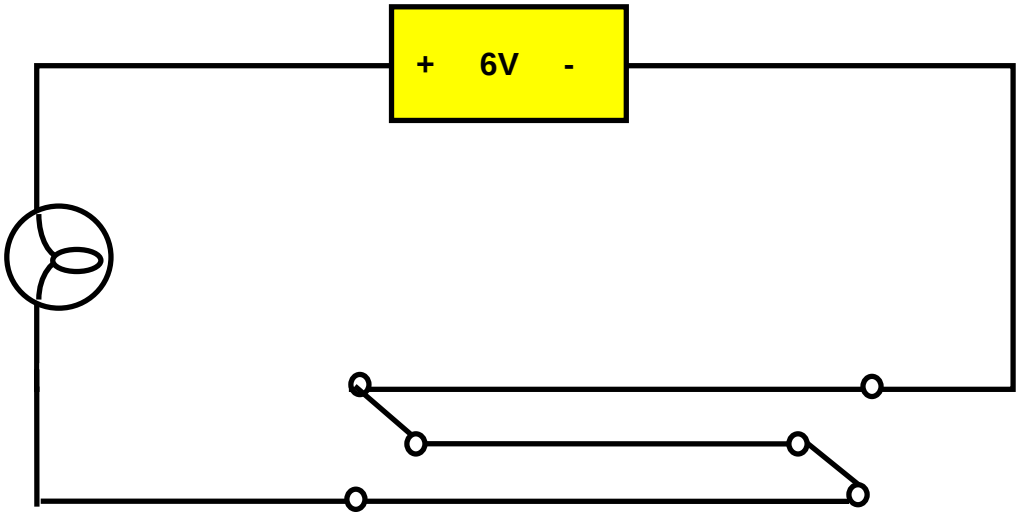
Does this work?

The circuit diagram for this is shown below .



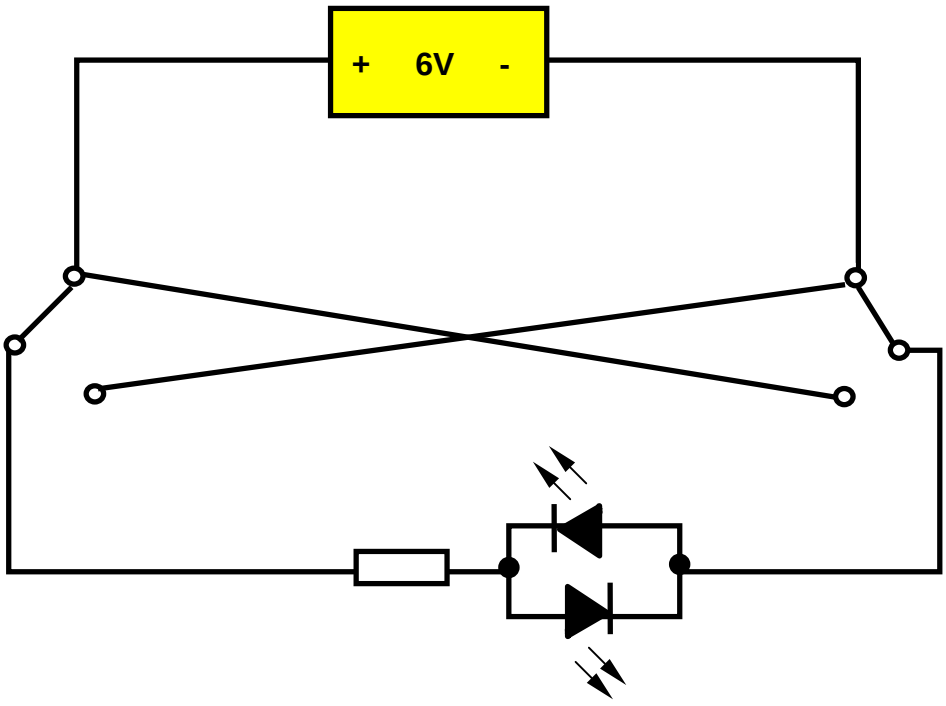
Copy the diagram four times. You should be able to draw the switch combinations (up/down) differently in each one. With a coloured felt tip pen, you should be able to show that in two of the diagrams, the electric current can flow from the battery, through a closed switch, through the lamp,

through the other closed switch and back to the battery. This means that the lamp is on. In the other two circuits, the one or both of the switches is open so the electricity cannot flow in a circuit and the lamp will be off



This is another way of wiring the switches. Can you see how it works?

Experiment 14. Reversing the direction of the Electric Current Flow (2)



In the circuit diagram above is a new circuit symbol - the bicolour led.

In this circuit, the two changeover switches should be operated at the same time. The two switches act together as a reversing switch. The bicolour led acts as a direction indicator. If a 6 volt motor is available, this may be used instead.

Build the circuit and try it out.

Copy the circuit diagram and use a coloured felt tip pen to draw arrows along the wires showing how the electric current flows round the circuit. **Current will only flow in a complete circuit - it will not flow in unconnected wires**. (Remember that current flows from + to -. If you cannot remember which way current will flow in a led, look back at experiment 6).

Copy the circuit again, but this time show one switch up and one down. Use coloured arrows to show the current flow this time.

Experiment 15. A Burglar Alarm (1 and 2)

We are going to design a burglar alarm. We will start with a simple circuit and improve it in stages.

We want our alarm to:

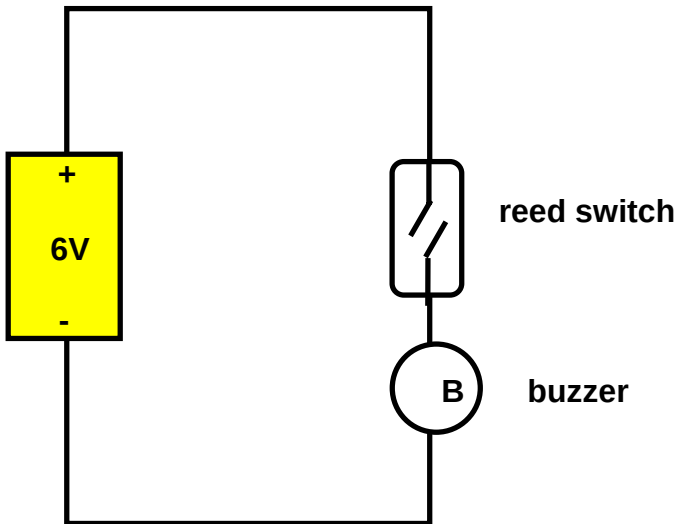
- **be triggered if a door is opened**
- **sound a buzzer when triggered**
- **keep sounding even if the door is then closed**
- **give a visual, as well as audible, warning**

Stage 1

We can use the reed switch and a magnet to detect whether a door is open or closed. In a real alarm system, a reed switch is mounted on a door frame and a magnet is mounted on the door. When the door is closed, the magnet and reed switch are close to each other and the switch operates (switches on). If the door is opened, the magnet and reed switch move apart and the reed switch switches off.

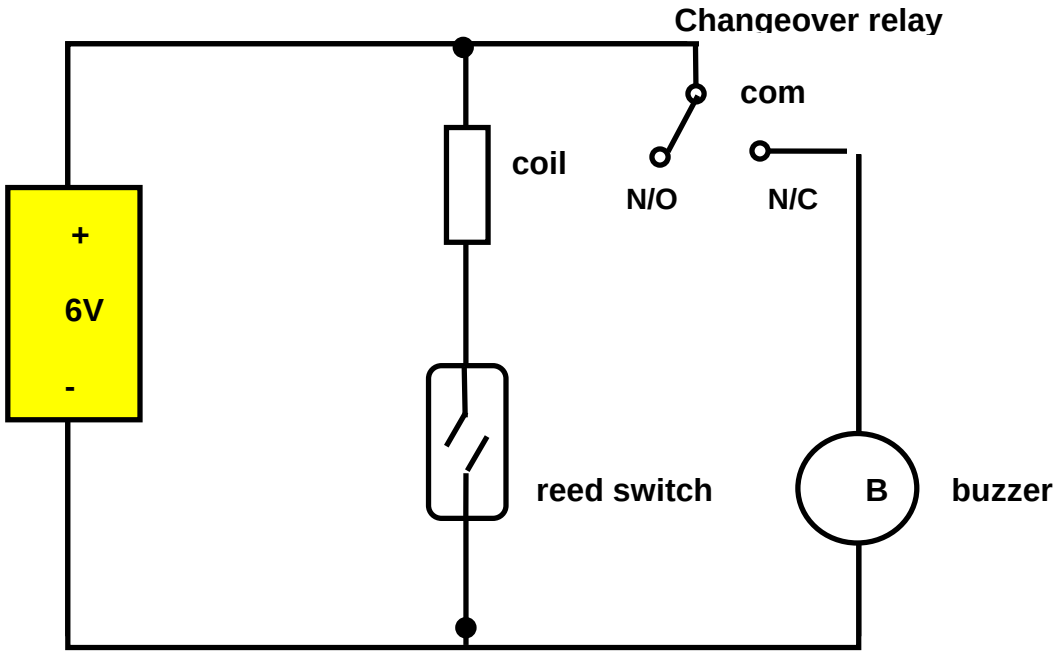
Using Boards 1 and 2, wire the reed switch in series with the buzzer and the battery (remember the buzzer only works if you wire it the correct way round). Bring the magnet close to the reed switch. What happens? This is the wrong way round! The buzzer only sounds when the magnet is close to the reed switch (i.e. the door is closed).

The circuit is shown below. For convenience, we have shown the battery on the left hand side.



Stage 2

We can use the reed switch to operate the changeover relay and use this to power the buzzer.

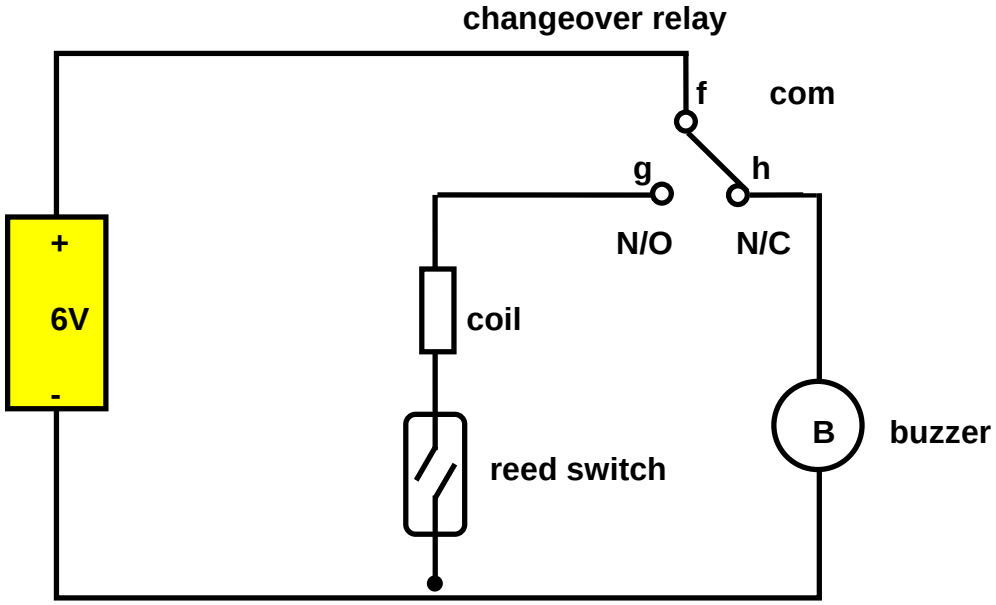


Build this circuit and test it.

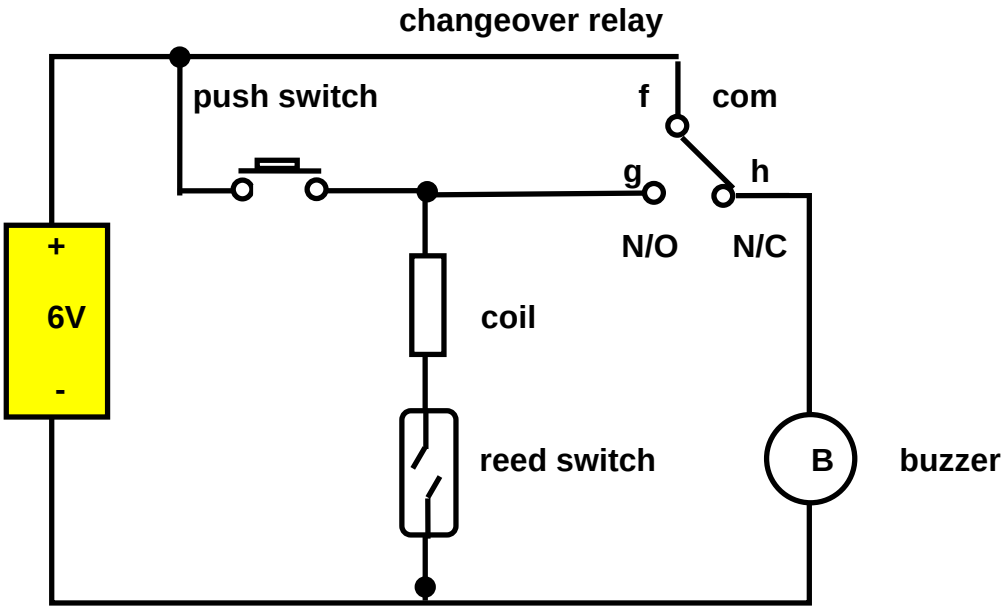
With the magnet next to the reed switch (door closed) the changeover relay is operated and the buzzer is switched off. When the magnet is removed (door open) the changeover relay coil switches off and the buzzer sounds. Unfortunately, when you put the magnet back (door closed again) the buzzer switches off.

Stage 3

We can use the changeover relay contacts to switch its own coil on and off. Make sure the magnet is close to the reed switch.



When we try this the buzzer sounds all the time because the relay coil is not powered.
We can get the relay to operate by briefly touching a lead between the battery + and the point g.
When this connection is made, the relay changes over and the coil is then powered through the relay contacts f - g. The lead can be replaced with a push switch as shown below.

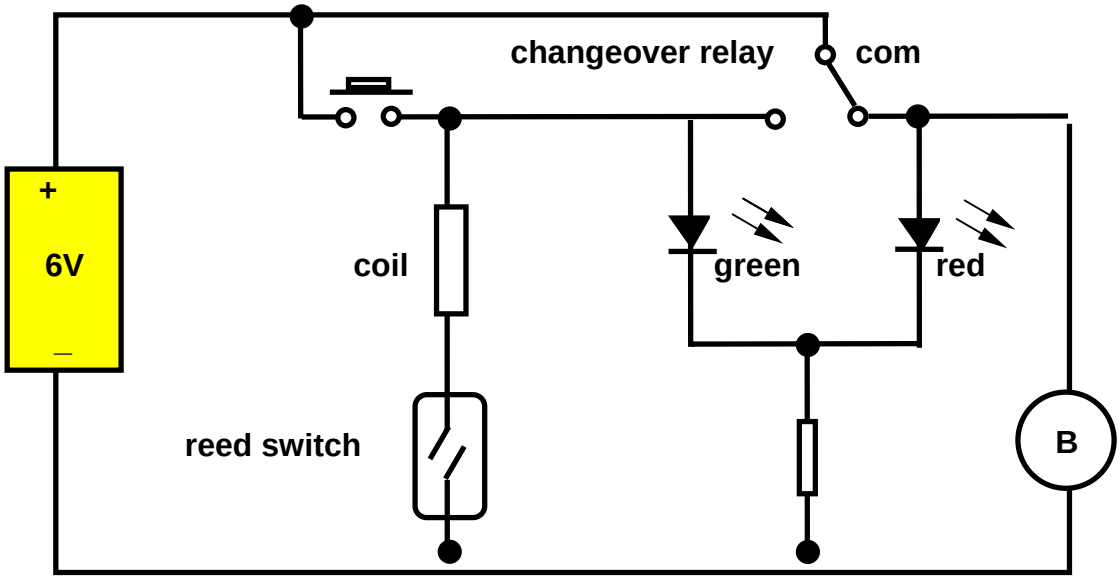


The relay will stay switched over until the coil current is interrupted, for example, if the magnet is removed from the reed switch. If we now replace the magnet (close the door) the relay still does not operate as the changeover relay contacts have broken the coil connection, and the buzzer continues to sound.

Stage 4

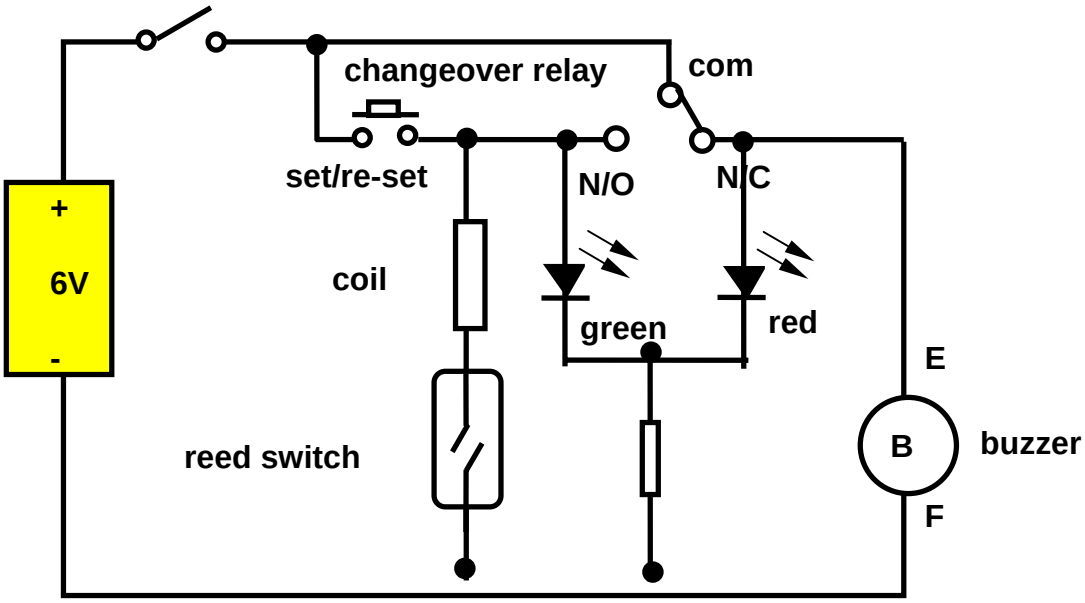
The visual indicators can now be added to the circuit. You can either use two lamps or the tricolour led.

In the circuit below, the tricolour led glows green when the alarm is not triggered and red when it is. We do this by wiring to the N/O and N/C contacts.



Stage 5

Finally, the alarm on/off switch can be added in series in the battery line - use one of the slide switches on board 1.



Carefully copy the circuit diagram and add the component letters from the circuit boards. As an example, the buzzer letters have already been added.

Write a set of instructions for someone to use your burglar alarm.

You must explain how to switch it on, how to set it, how to re-set it if it is triggered and how to switch it off.

Appendix

Choice of Power Supply

The Basic Electricity Boards require a 6 volt d.c. power source.

We recommend the use of a mains powered low voltage power supply for this as it negates the ongoing cost of battery replacement.

The ideal type is a regulated supply as the voltage does not vary when differing loads are applied.

Electrosound offer several suitable power supplies as indicated in our catalogue.

Suitable regulated supplies are:

- **Budget 6V, 1A**
- **1ASWD**
- **Spider ***

* The Spider is the ideal unit for this work as it offers 1.5, 3, 4.5 and 6 volts through 4 sets of terminals. This allows four groups to use it simultaneously.

Alternatively, we can supply a **Battery Holder** which holds four D type cells (HP2) and allows voltages of 1.5, 3, 4.5 or 6V to be selected.

Replacement Lamps

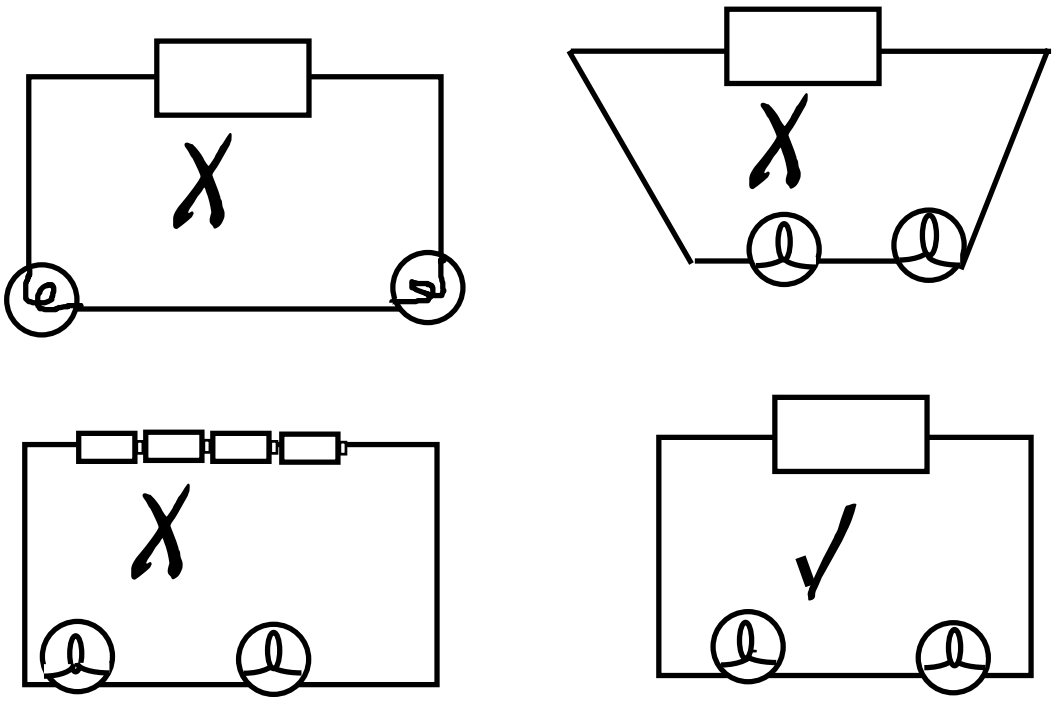
A problem often arises when the lamps on the board are wired in series. The children, quite reasonably, expect them to be the same brightness. In an ideal world this should be so, but manufacturing tolerances mean that it is seldom the case. It is useful to experiment with various

lamps to ensure that all the lamps on the board glow with the same brightness. A little time setting this up before the lesson saves a lot of heartache and confusion during the lesson!

Drawing Circuit Diagrams

There are some simple rules for drawing circuit diagrams. They are:

only use circuit symbols
use only straight lines to draw wires
wires should only be drawn horizontally or vertically
wires are drawn joined to opposite sides of symbols



Extension Work and Questions

1. Draw circuit diagrams for as many different circuits that you can think you can make using up to six leads and three lamps powered from one 6v battery. You do not have to use everything for each circuit. I can think of seven, how many can you think of?

2. Four 6 volt lamps are wired in **series**. What voltage would be needed to make them glow at full brightness?

3. Four 6 volt lamps are wired in **parallel**. What voltage would be needed to make them glow at full brightness?

4. Design and build a Morse code sending device.

5. Make a list of five electrical conductors and five electrical insulators.

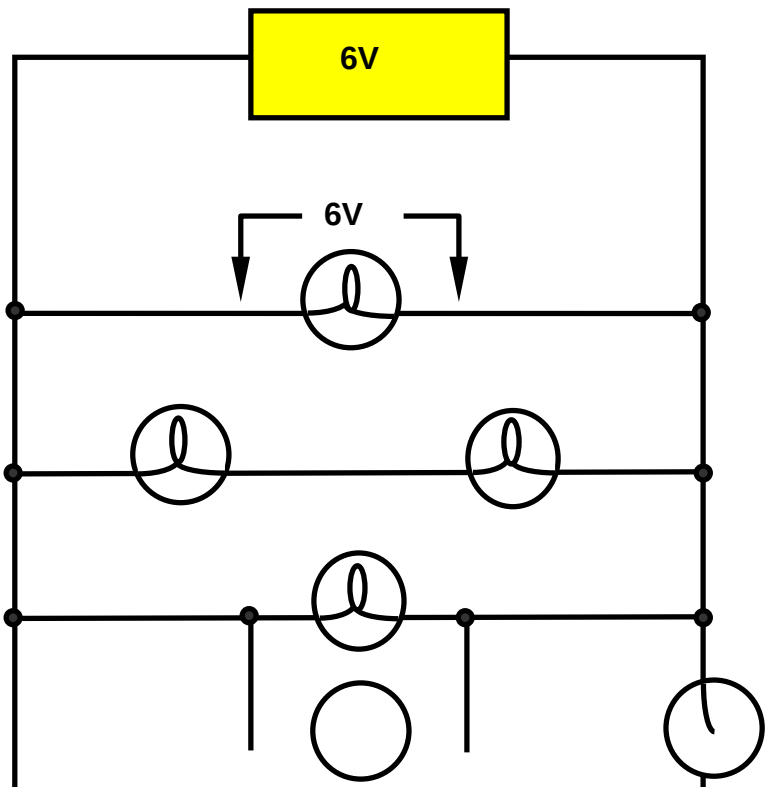
6. Find out about fuses. Where would you put a fuse in a parallel circuit to protect the whole circuit?
7. Design a circuit with 3 lamps and two switches. One switch should control one of the lamps and the other switch should control the other two lamps. All the lamps should glow at full brightness when switched on.

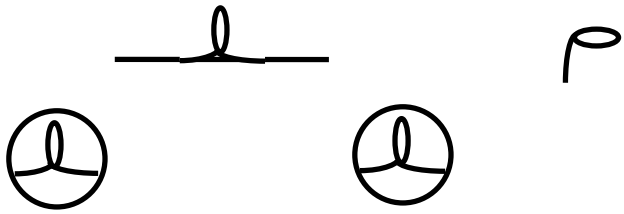
8. Electricity is a form of energy that can be easily converted into other forms of energy. Other forms of energy include heat, light, movement and sound.

For each of the following, say what form (or forms) of energy the electricity is converted into:

electric fire
light bulb (lamp)
radio
food mixer
television
telephone
toaster
fluorescent tube
vacuum cleaner

9. Copy the circuit diagram below and mark on it the voltage across each lamp. The first one has been done for you.





10. Look at the final circuit for the burglar alarm. At the moment only one reed switch is used, protecting one door. Redesign the circuit to add a second reed switch, which can protect another door (or window). The alarm should trigger if either door is opened. Using one board 1 and two board 2s, try out your circuit.

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