

Black Box System

Teachers'/Pupils' Guide

The Black Box System comprises a series of components that may be connected together using 4mm plugged leads. Most of the components are hidden beneath the surface of the box except for those that actually need to be seen or manipulated (e.g. lamps, leds, potentiometers etc.).

There are virtually an infinite number of experiments that may be performed with the system. Initially we will confine ourselves to some experiments using the Starter Kit, which comprises 3x lamp, 3 x single pole switch, 2 x changeover switch, 1 x push switch, 1 x buzzer, 1 x traffic light set, 1 x component holder, 1 x 4xAA cell holder and 10 x 4mm plugged wire.

The experiments are supplied in a logical order to promote understanding of the electrical principles involved.

Before starting please fit 4, AA cells into the holder observing correct polarity. We will now refer to this as the battery. (A battery consists of two or more cells connected together)

Lighting a Lamp

Using two wires connect the battery to the lamp. It should light. Now unscrew the lamp. What happens?

Adding a Switch

Pull one of the wires out of the battery and plug a third wire into the battery. You should now have two "spare" ends of wires and the lamp should not light. Touch the two spare wire ends together. What happens? You have now made a simple switch!

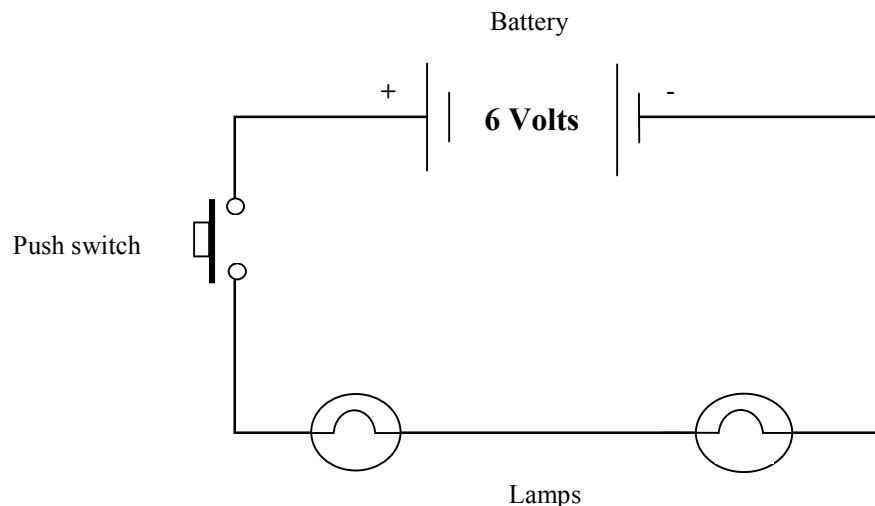
Lamps in Series

Plug the two spare ends into the push switch module and check that it does as you expect. Now unplug one end of one of the wires (it doesn't matter which) and plug it into another lamp. Take a new wire and plug one end into the other side of the lamp and the other into the spare socket. Push the switch. What happens? Are the lamps the same brightness as before? Unscrew one of the lamps and push the switch. What happens? Screw the lamp back in and unscrew the other one. Once again push the switch. What happens? This is known as SERIES wiring .

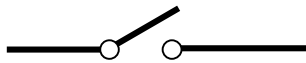
When we connect electrical components together in this way we are making what is called a CIRCUIT. In a circuit you can trace the electricity from one side of the battery, through the components and back to the other side of the battery.

We could draw all the components that we have used so far, wired up as in the last experiment. However, this could become quite messy and so a simpler way of showing what is happening has been developed. It is called a CIRCUIT DIAGRAM and uses CIRCUIT SYMBOLS.

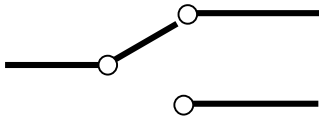
Circuit Diagrams



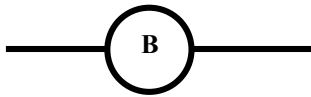
We will be using a few more circuit symbols, so here they are:-



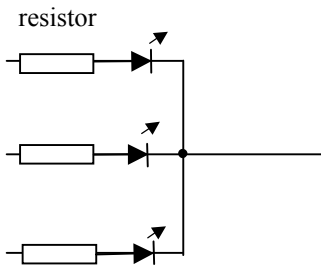
Single Pole Switch



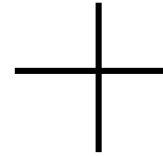
Changeover switch (C/O switch)



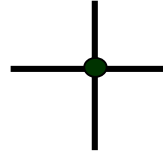
Buzzer



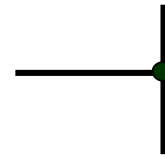
Traffic Light LEDs



Wires crossing but not connected together



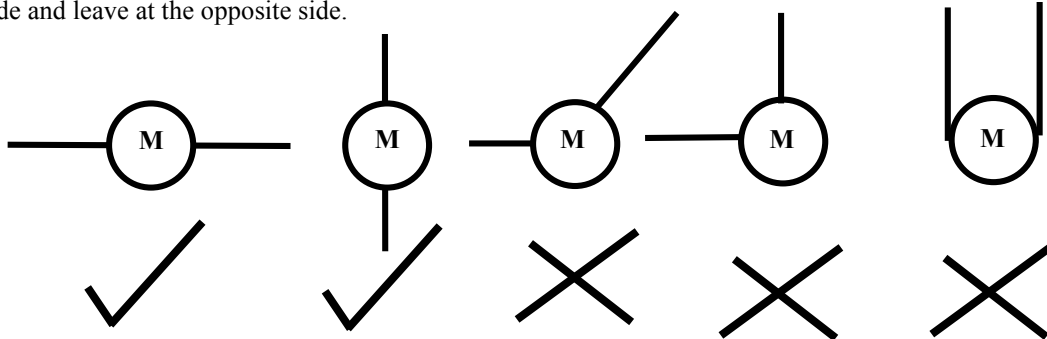
Wires connected together



Wires connected together

It will be noted that some of the components have a red and black socket rather than two black sockets. These components will only work one way round. The red terminal should be connected nearest the red (+) battery terminal.

We generally try to draw a circuit diagram as a square. The leads to a component symbol come in at one side and leave at the opposite side.



Your turn

Draw a circuit diagram of a buzzer, a single pole switch and a battery in series.

Lamps in Series - a bit more

The lamps in a series circuit share the battery voltage between them. If the lamps are absolutely identical (they seldom are), they will share the voltage equally. Thus the two lamps in the circuit above will each have 3V across them giving a total of 6V (from the battery). As they are 6V lamps this means they will only be half as bright as they normally would be.

If you wired three, 6V lamps in series how would their brightness compare with two lamps in series? What would be the voltage across each of the lamps?

In a series circuit you can trace the flow of electricity right around the circuit. There are no branches.

Conductors and Insulators

Materials that allow electricity to easily flow through them are called CONDUCTORS. Materials that do not allow electricity to flow through them are called INSULATORS (or NON CONDUCTORS).

We can use the component holder to test various items.

Wire up a circuit with the battery, a lamp and the component holder in series. The lamp should not light at this stage.

Touch either end of another wire to the two crocodile clips and the lamp lights – you have just tested the wire. Is it a conductor or an insulator?

Now try laying the plastic coating on the wire across the two clips. What happens (if anything)? Plastic is an insulator.

Try various other things in the same way and make up a list of conductors and insulators. Suitable things to test might be:- paper, paper clip, scissors, cardboard, glass, wood, cellophane etc.

What do you notice about all the things that conduct electricity?

Switches are made of a combination of conductors and insulators. The contacts and a bridge, which connects them together, are made of brass and the other bits of the switch are made of plastic.

Lamps in Parallel

There is another way of wiring several lamps to a battery. Using six wires see if you can connect three lamps to the battery in such a way that all the lamps are at full brightness. You must use all six wires!

Draw a circuit diagram of your circuit.

This type of wiring is called parallel wiring. Using a different colour pencil for each lamp, trace the electricity from the battery to each lamp and back to the battery.

Now unscrew one of the lamps. What happens? Can you explain why the other lamps are still shining?

Using one extra wire and a single pole switch, see if you can change the circuit so that the switch switches all three lamps either on or off.

Draw a circuit diagram of your new circuit.

A Morse code Sender

Samuel Morse developed a way of transmitting information long distances before the telephone was invented. It depended on sending either a dot (short beep) or a dash (long beep) along wires. The Morse code for SOS (Save Our Souls) is ...---... We can see that S is three dots and O is three dashes. Use the Internet to search for Morse code and copy down the alphabet.

If we could make a Morse code sender, we could signal our friends. You can make your own version using a battery, the buzzer, a push switch and three wires. (Or a silent version using a lamp instead of the buzzer.)

Draw a circuit diagram of your Morse sender, have your teacher check it and then build the circuit.

Send a secret message to a friend. You should write down what you are sending and your friend should write down what he receives. Compare them at the end. How accurate were you?

Traffic Lights

By now you should be pretty good at drawing circuits and making them. The traffic lights module is rather special because it contains three Light Emitting Diodes (LEDs) and three resistors wired together. The reason for this is that if we used separate modules we would need six modules and a load of wires, which would make building the circuit very difficult. The LEDs will blow if they have more

than 2V across them. The resistors are conductors that are not very good, and so when we put them in line with an LED they stop the voltage from getting too high across the LED.

You will also notice that the LED symbol is an arrow with a bar at the pointy end (see page 2). The arrow shows the direction the electricity must flow, the bar shows that it will block electricity in the other direction and the small arrow show that something (light) is given out.

This is all very well but in which direction does electricity travel? Is it from positive (red) to negative (black) or from negative (black) to positive (red)? You can find out for yourself by connecting the battery to one of the LEDs. One way round it will work and one way round it won't!

Using the traffic lights module, the battery module and three single pole switches see if you can develop a working set of traffic lights. Find out which order traffic lights light up and then try it for yourself.

The Changeover Switch

If you look at the circuit symbols on page 2, you will notice that we have not used the changeover switch yet. This is a special switch that allows either one circuit to be live or another circuit to be live. In other words it does not have an off position, rather either of two on positions.

Try, using 5 wires, to use the switch to select between two lamps.

By using 1 battery, 2 c/o switches, one lamp and 5 wires it is possible to produce a system like that at home, where a downstairs switch and an upstairs switch control a single lamp. Try it out for yourself. This is extremely difficult. Each switch should turn the lamp on/off and you should be able to switch the lamp on with one switch and off with the other.

Short circuits

A short circuit is usually an undesirable thing. It usually means that you have made a mistake! We are going to make a deliberate short circuit to find out about them.

Wire two lamps in series with the battery. Using an extra wire, connect it across one of the lamps. What happens? Can you explain why it happens?

A short circuit means that electricity is diverted away from where you need it. If you short-circuit the battery terminals, the battery life will be severely shortened and the wire may get hot. Never deliberately introduce a short circuit.

Series Parallel Wiring

We can combine series and parallel wiring in one circuit. Using 4 wires connect two lamps in parallel to the battery. Check that the lamps light. Now remove one of the wires from the battery (either side) and plug it into a third lamp. Connect the other side of the lamp back to the battery using another wire. You should be able to answer the following questions: Try to answer them first and then check your answers by experiment.

1. What is the voltage across each of the lamps?
2. Which lamp must you unscrew to turn all the lamps off?
3. Where would you place a switch to turn one of the parallel wired lamps off? (to try this you will also need an extra wire) What would happen to the other parallel lamp?

Electric Current

We have talked about electricity flowing around the circuit. We call what actually flows, **ELECTRIC CURRENT**. Current flows from the positive terminal of the battery, round the circuit and comes back into the negative battery terminal. Current is measured in Amperes (Amps). Unscrew one of the lamps and read what it says on the metal part just below the glass. It should say something like 6V, 0.06A. This means that the lamp is designed to run with 6Volts across it and is designed for 0.06A of current to flow through it.