Contents

Page

Sections

1. Basic electrical principles and theory 1
2. Electrical supply and distribution 11
3. Legislation and Regulations 19
4. Treatment for electric shock 37
5. Basic domestic electrical installation theory: 45
   - Domestic circuits 46
   - Earthing and Earth Continuity 49
   - Earthing and Bonding 49
   - Types of domestic electrical earthing system 54
   - Safety requirements when working on electrical systems 57
   - Identifying electrical equipment 59
   - Secure Isolation 61
   - Electrical materials and basic fixing components 63
6. Common electrical components used in domestic heating and hot water systems 71
7. How central heating system wiring and components come together 83
8. Fault finding 103

Assessment Check – Answers 125

Section 1

Basic electrical principles and theory

Section 1 Basic electrical principles and theory

What is electricity?

Put simply, electricity can be defined as the controlled "flow of electrons through a conductor".

This sounds simple but it's important to be clear about what the definition means. As plumbers and gas installers, few will have difficulty in understanding the term 'flow', as we study water and gas regularly and understand that water and gas flows through pipes – electricity flows through conductors in a similar way.

The terms 'electron' and 'conductor' may not be so familiar and require more thorough explanation.

This will require a brief exploration of the microscopic particles of matter that make up all substances, namely molecules and atoms.

Molecules and Atoms

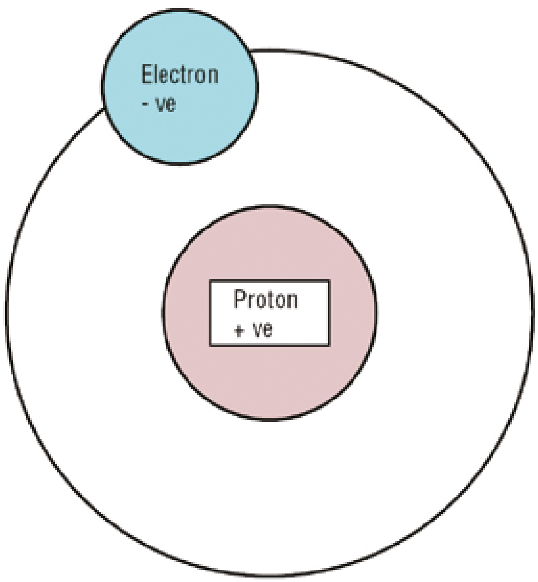
Molecules

All substances are made up of molecules. A molecule is a very tiny particle of matter, visible only through a microscope. Molecules exist in a state of rapid motion and the ease with which they move around determines the **state** of the substance they form.

- When molecules are densely packed together and their movement is restricted the substance formed by them is **solid**;
- In situations where the molecules are less densely bound together, and where they can move more freely, the substance formed is **liquid**;
- In situations which allow the molecules almost unrestricted movement the substance formed is **gas**.

Solids, Liquids and Gases are also referred to as the three states of matter.

To fully understand the nature of electrons it is necessary to break molecules down further and look at atoms.



Atoms

Atoms are the smallest parts of matter, but can themselves be broken down into constituent parts:

– A **nucleus** which contains **protons** and **neutrons**. Protons have a positive charge (+) and neutrons are electrically neutral (that is they have no charge). Neutrons are the adhesive force that holds the nucleus together.

– **Electrons**, which allow electricity to flow through atoms. Electrons contain a negative charge (-).

All atoms contain equal numbers of **protons** and **electrons** and in this state the matter is said to be electrically neutral (in other words no electricity is flowing). In some cases it is possible to add or remove electrons to a neutral atom to leave it with a positive (+) or negative (-) charge.

Within the atom, if the electrons which orbit the nucleus "break free" and flow to a neighbouring atom **electricity** will be flowing.

To ensure a constant flow of electricity it is necessary to give the electrons a bit of an external kick to encourage them to flow easily. From then, providing control is kept of the amount of electrons being pushed and pulled around the circuit, electricity will be flowing.

The external kick supplied is called a **voltage**, measured in Volts and is sometimes called Electro Motive Force or EMF.

Electricity flows through some materials more easily than others. The materials through which electricity flows most easily are considered to be good conductors.

What are conductors?

Conductors are materials through which it is easy to get the electrons to flow with a bit of external stimulation. Materials in which it is very hard to get electrons to flow are known as insulators. Examples of material which make good conductors are gold, copper and aluminium. Typical insulator materials include wood, plastic and rubber.

Measuring Electricity

Current

As the single electron is only a very tiny part of an atom, it is much too small a quantity to have any practical use in measurement terms. In order to measure electrons effectively they are grouped into units called **Coulombs** – a coulomb consists of approximately 6,240,000,000,000,000,000 electrons! Therefore electrical flow relates to the number of coulombs (millions of electrons) per second through a conductor.

In electric circuits the **electric current flow** is measured in **Amperes** (usually abbreviated to **Amps** and given the symbol **I**).

One **Ampere** is defined as a flow of one coulomb in one second – in other words the quantity or amount of electricity that flows every second.

Note: The amount of current flowing in Amps is measured using an instrument called an Ammeter which will be covered in more detail later.

We have mentioned two important electrical quantities – current, measured in Amps and voltage (remember the external kick) which is measured in Volts. The third important quantity that must be considered when dealing with electrical circuits is resistance.

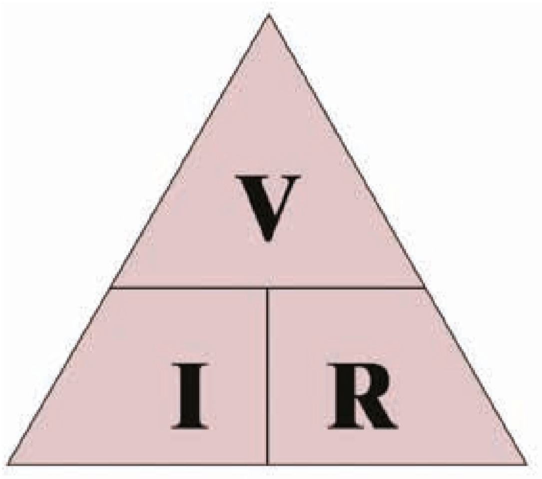
Resistance

Resistance in an electrical circuit is measured in units called **Ohms** (denoted by the Greek letter Ω (Omega) and given the symbol **R**). In basic terms, resistance relates to the conductivity of the material used to form the circuit: the better a material conducts electricity, the lower the resistance to current flow will be.

Ohm's Law

The three quantities voltage, current and resistance are used frequently by electricians and they all inter-relate. You cannot have a practical electric circuit that does not have voltage, current and resistance. It is possible to calculate any of the three quantities if we know the other two using a basic rule known as "Ohm's Law".

Ohm's Law can be shown as a formula and is often represented using a format known as the "Ohm's Law Triangle".



By using the Ohm's Law Triangle it is possible to calculate the quantities that make up electrical circuits in the following ways:

Suppose you want to determine the voltage **V** of a circuit and you know the current **I** and Resistance **R**.

- Covering the **V** with your finger shows you that you need to **multiply** the current **I** by the resistance **R** to find voltage **V**.
- To find the current **I**, cover **I** and you see that you now need to **divide** voltage **V** by resistance **R** as **V** is shown above **R**.
- To find **R** cover it up and you will see that you need to **divide** the voltage **V** by the current **I** to find the resistance.

Try a few of examples for yourself where we have added some quantities.

1. If the voltage supplied to a circuit was 20 volts and a current of 1 ampere flowed. Calculate the resistance of the circuit.
2. A circuit has a resistance of 100 Ohms and a current of 2 Amps is flowing. What would be the voltage applied to the circuit?
3. Calculate the current flowing in a circuit with a resistance of 100 Ohms and a voltage supply of 240 Volts.

Answers

1. R = V/I = 20/1 = **20 Ohms**
2. V = I x R = 2 x 100 = **200 Volts**
3. I = V/R = 240/100 = **2.4 Amps.**

[Example 3 is how you calculate the required fuse rating for any given circuit or appliance]

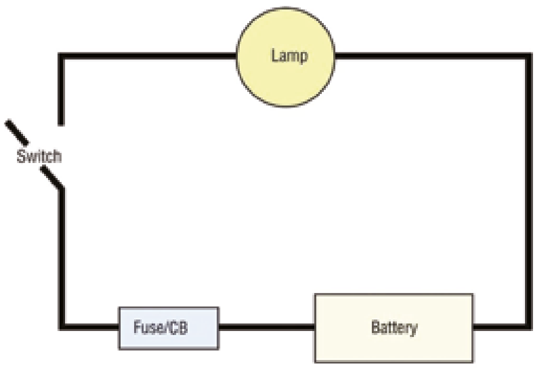
How Circuits Work

A simple electric circuit can be produced by bending a conductor such as a copper wire into a loop and connecting it to the terminals of a battery. However, this simple model circuit would be unsuitable for practical use.

All electrical circuits in practical use must have:

- Conductors through which current can flow (usually copper wire)
- A voltage connected across the ends to provide a potential difference and to make a complete circuit (such as a battery)
- A load such as a lamp or device that needs electric current to make it work but will also limit the amount of current flowing because it has a high resistance.
- A device such as a fuse or circuit breaker to protect the circuit should too much current flow.
- A switch for opening and closing the circuit to switch the current on and off

The diagram below shows a practical electric circuit containing a battery as a supply source, a lamp as a load, a switch to open and close the circuit and a fuse to protect the circuit from excess current flow. When we close the switch the voltage available from the battery will push electrons through the lamp which has a resistance which will control the amount of current that flows in the circuit. If we get a problem, such as a short circuit where much more current than normal flows, then the fuse or circuit breaker (a circuit breaker is often referred to as a CB) will operate and stop the dangerous current from flowing.



Note: A switch opens the circuit and **prevents** the electricity from flowing until we close it again. This is different when we think of gas and water as when we open a valve or tap we **enable** the gas or water to flow:

Open switches – **prevents** electricity flowing

Open valves and taps – **enables** gas and liquid to flow.

Fuses and Circuit Breakers

Why are fuses needed?

Fusing is a safety measure which aims to prevent high electrical current passing through wires that are not designed to carry such large current. This is important because flowing electrical current causes a temperature rise in the material through which it is passes. If a current is too high for the wire it passes through, the resulting overheating effect presents a serious risk of fire.

As a general rule, the thicker the wire, the higher the current that can flow through it. This is why larger cables are used for power circuits than for lighting circuits – because power circuits supply equipment that needs higher current such as electric heaters, cookers, electric showers etc.

How do fuses help?

The various different types of fuse that exist all contain fuse wire. The fuse wire will melt or 'blow' if electric current above the specified amount is passed through it. In BS 7671 the definition of a fuse was changed from blow to melt. Fuses come in different sizes to protect against different levels of current. They are either the disposable type or need to have the wire replaced in order to reset them.

In modern electrical installations you'll tend to come across the circuit breaker (CB). A CB is a device which will trip a switch to break the electrical circuit if excessively high current flows, but can be reset without the use of tools. The British Standard number for CBs is BS EN 60898.

When electricity flows it also produces a magnetic field around the conductors in addition to also producing heating (as previously mentioned). The CB operates by detecting a combination of the heating and magnetic effect to break the circuit if a fault occurs. These are more accurate than fuses and are re-settable. CBs are now found in all consumer units installed in new domestic properties.

Another special protective device with which you will come into contact is the Residual Current Device (RCD). This is a highly sensitive device providing a high degree of protection to high risk parts of electrical systems and to provide sufficiently quick disconnection times where loop impedance values are too high for fuse or circuit breaker disconnection times. BS 7671 sets out the requirements for the installation of RCDs and as a result they have become much more commonplace. An RCD is often installed within a consumer unit in modern houses to protect parts of the electrical installation such as socket-outlet circuits, circuits where cables are concealed behind walls (subject to certain criteria) and special locations such as locations containing a bath or shower. There are various BS numbers for RCDs but the most common are BS EN 61008-1.

N.B. the BS EN 61009 device is an RCD and CB combined and is known as an RCBO.

Older BS 3871 MCBs (miniature circuit breakers) are still in use and do not need replacing unless they are faulty.

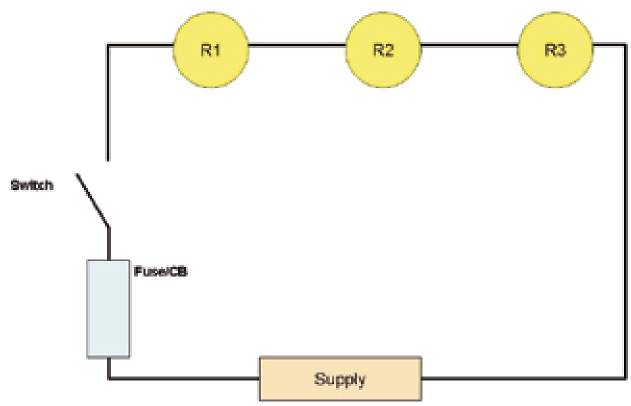
More information on fuses, CBs and RCDs is provided later in the manual.

Circuits

There are two very basic types of electrical circuit. These are series circuits and parallel circuits.

Series circuit

If we take a number of different resistors (items of electrical equipment such as lamps etc.) and connect them together end to end and then connect the free ends to a battery we will find that the current will only have one route to take around the circuit. This type of connection is known as a series circuit. In heating systems, most switches and other controls such as thermostats are usually connected 'in series'.



Section 8

Fault finding

Assessment Check – Answers