

Chapter 7: Mains Electricity

We use mains electricity, supplied by power stations, for all kinds of appliances in our homes, so it is very important to know how to use it safely. In this chapter you will learn how mains electricity is brought into our homes and supplied to appliances. You also will read about devices that protect users from electric shocks.

Using electricity



Figure 7.1 We use a huge amount of electricity every day for heating and lighting.

When you turn on your computer, television and most other appliances in your home the electricity you use is almost certainly going to come from the **mains supply**. This electrical energy usually enters our homes through an underground cable. The cable is connected to an **electricity meter**, which measures the amount of electrical energy used. From here, the cable is connected to a **consumer unit** or a **fuse box**, which contains fuses or circuit breakers for the various circuits in your home. Fuses and circuit breakers are safety devices which shut off the electricity in a circuit if the current in them becomes too large (see page 61).

Most of the wires that leave the fuse box are connected to **ring main circuits** that are hidden in the walls or floors around each room. Individual pieces of electrical equipment are connected to these circuits using plugs.

Ring circuits usually consist of three wires – the live wire, the neutral wire and the earth wire.

The **live wire** provides the path along which the electrical energy from the power station travels. This wire is alternately positive and negative causing **alternating current (ac)** to flow along it.

The **neutral wire** completes the circuit.



Figure 7.2 Consumer unit in a house.

Ring main circuits provide a way of allowing several appliances in different parts of the same room to be connected to the mains using the minimum amount of wiring. Imagine how much wire would be needed if there was just one mains socket in each room.

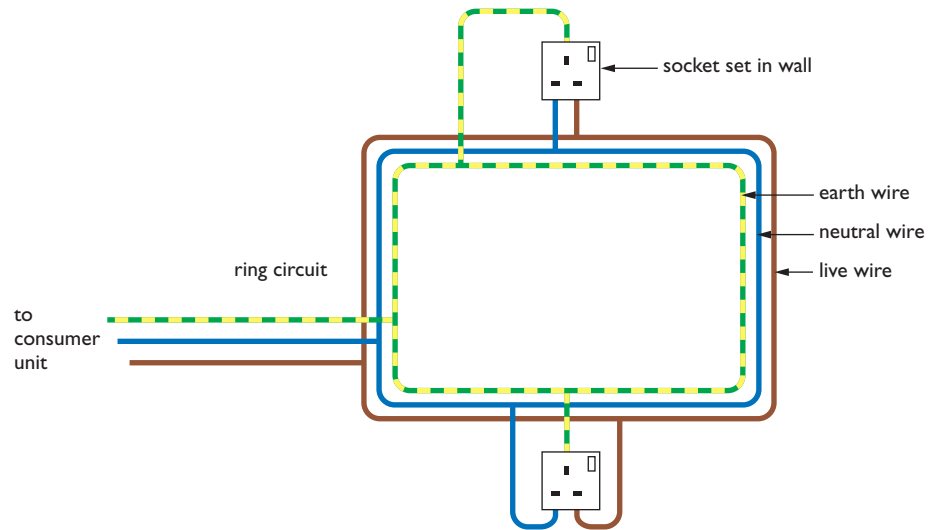


Figure 7.3 Ring mains help to cut down on the amount of wiring needed in a house.

The **earth wire** usually has no current flowing through it. It is there to protect you if an appliance develops a fault.

Plugs and sockets in different countries look different, but the principles of electrical wiring are similar.

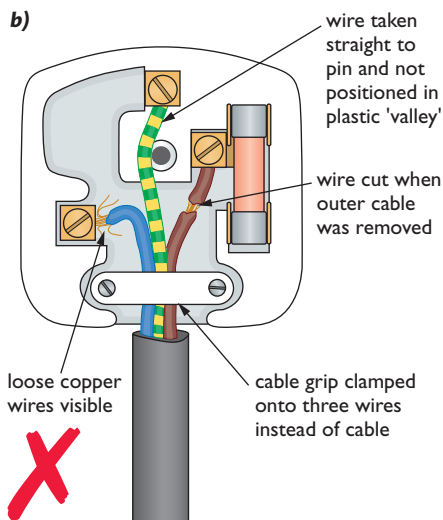
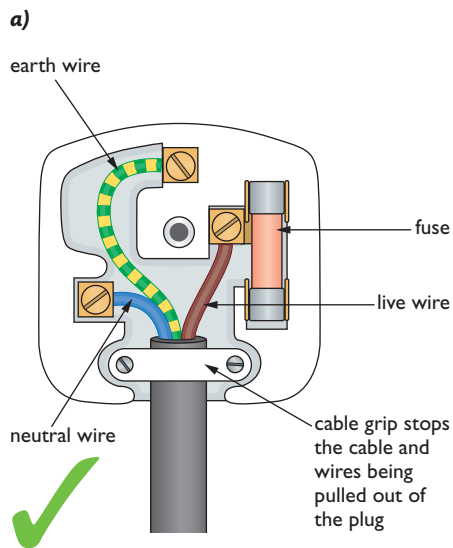


Figure 7.5 a) A correctly wired UK plug.
b) How not to wire a plug!



Figure 7.4 Plug sockets in the UK and in Portugal.

Mains electricity is supplied to homes in the UK at about 230 V. This is a much higher voltage than the cells and batteries used in portable electrical appliances. If you come into direct contact with mains electricity you could receive a severe electric shock, which might even be fatal. The outer part of a plug, called the casing, is therefore made from plastic, which is a good insulator. Connections to the circuits are made via three brass pins, as brass is an excellent conductor of electricity. Figure 7.5b shows some common mistakes made when wiring a plug. This figure shows the inside of a 3-pin plug used in the UK, but similar principles apply to all kinds of plug.

Using electricity safely

Electricity is very useful, but it can be dangerous if it is not used safely. There are safety devices built into houses and electrical appliances that you will learn about later, but there are things we can do to keep ourselves safe as well.

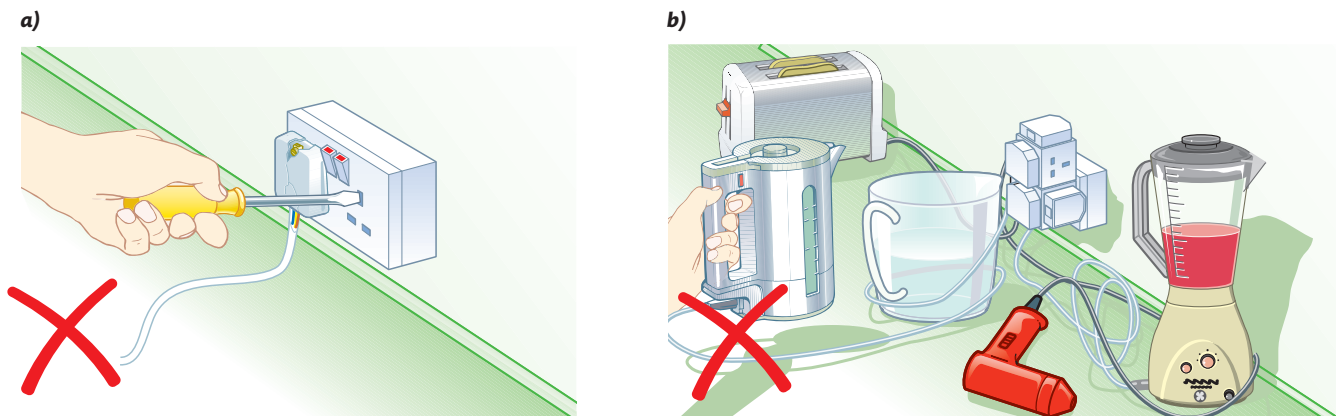


Figure 7.6 Some electrical hazards.

Figure 7.6 shows some of the following hazards of electricity that can easily be avoided. Broken plugs and frayed wires can expose the metal wires or parts of the plug that are carrying the electricity. Anyone touching these would get an electric shock, so they should be replaced as soon as the damage occurs. Anyone poking a metal object into a socket will also get an electric shock. Cables to electrical appliances should be kept as short as possible to prevent them causing spills. Water can conduct electricity at high voltages, so spilling water onto electrical equipment can be dangerous. Water should also be kept away from sockets and you must never use electrical equipment with wet hands.

Safety devices

Fuses

Many plugs contain a fuse. The fuse is usually in the form of a cylinder or cartridge, which contains a thin piece of wire made from a metal that has a low melting point. If too large a current flows in the circuit the fuse wire becomes very hot and melts. The fuse “blows”, shutting the circuit off. This prevents you getting a shock and reduces the possibility of an electrical fire. Once the fault causing the surge of current has been corrected, the blown fuse must be replaced with a new one of the same size before the appliance can be used again.

There are several sizes of fuses. The most common for domestic appliances are 3 A, 5 A and 13 A. The correct fuse for a circuit is the one that allows the correct current to flow but blows if the current is a little larger. If the correct current in a circuit is 2 A then it should be protected with a 3 A fuse. If the correct current is 4 A then a 5 A fuse should be used. It is possible to calculate the correct size of fuse for an appliance but nowadays manufacturers provide appliances fitted with the correct size of fuse.

Modern safety devices such as those you might find in your consumer unit are often in the form of **trip switches** or **circuit breakers**. If too large a current flows in a circuit a switch opens making the circuit incomplete. Once the fault in the circuit has been corrected, the switch is reset, usually by pressing a reset button. There is no need for the switch or circuit breaker to be replaced, as there is when fuses are used. The consumer unit shown in Figure 7.2 uses circuit breakers.

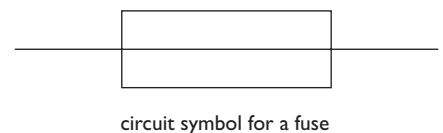


Figure 7.7 Fuses are important safety devices in electrical appliances.

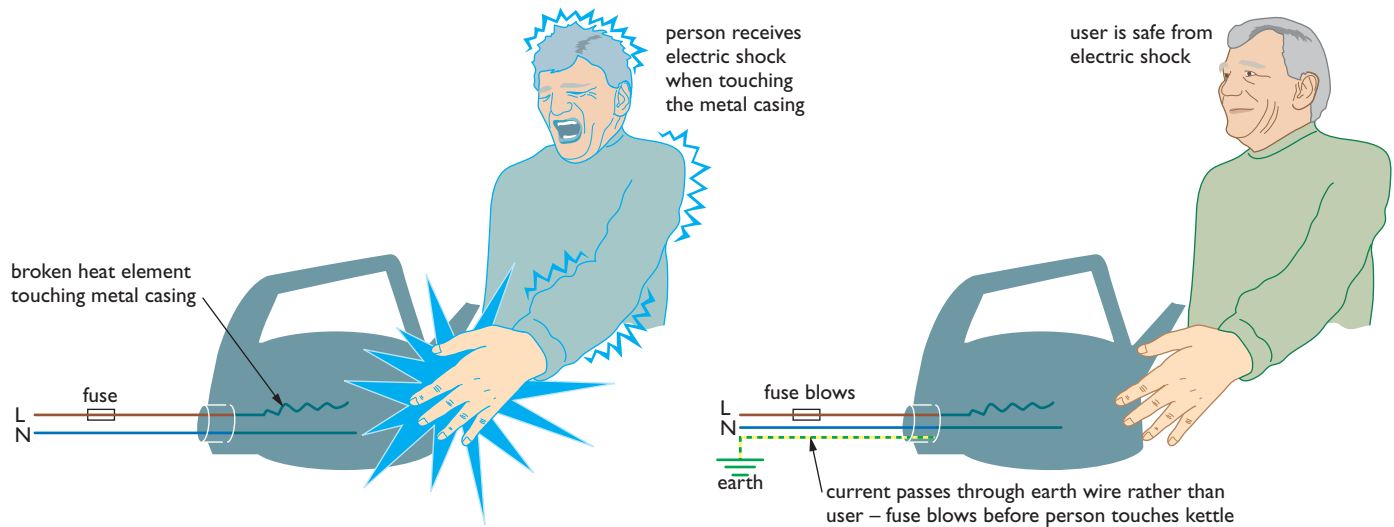


Figure 7.8 The earth wire provides protection when electrical appliances develop a fault.



Figure 7.9 This plastic kettle has double insulation which means that there is no need for an earth wire.

Earth wires and double insulation

Many appliances have a metal casing. This should be connected to the earth wire so that if the live wire becomes frayed or breaks and comes into contact with the casing the earth wire provides a low-resistance path for the current. This current is likely to be large enough to blow the fuse and turn the circuit off. Without the earth wire anyone touching the casing of the faulty appliance would receive a severe electric shock as current passed through them to earth (Figure 7.8).

Some modern appliances now use casings made from an insulator such as plastic rather than from metal. If all the electrical parts of an appliance are insulated in this way, so that they cannot be touched by the user, the appliance is said to have **double insulation**. Appliances that have double insulation use a two-wire flex. There is no need for an earth wire.

Switches

Switches in mains circuits should always be included in the live wire so that when the switch is open no electrical energy can reach an appliance. If the switch is included in the neutral wire, electrical energy can still enter an appliance, and could possibly cause an electric shock (Figure 7.10).

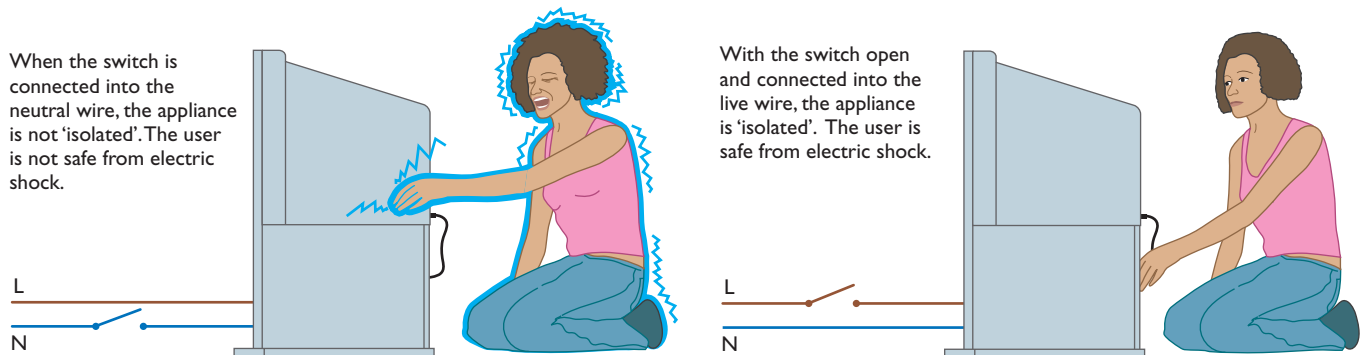


Figure 7.10 The switch in a circuit should be in the live wire.

The heating effect of current

The wiring in a house is designed to let current pass through it easily, and we say that it has a low **resistance**. However things such as the heating elements in kettles or toasters (Figure 7.11) are designed to have a high resistance. As the current passes through the element, energy is transferred and the element heats up. We use the heating effect of current in many different ways in our homes. You will learn more about resistance in Chapter 10.

In the kitchen shown in Figure 7.12 the heating effect of electricity is used in the toaster, kettle, dishwasher, cooker and washing machine. It is also used in the lights – normal light bulbs have a very thin filament which gets so hot when current passes through it that it glows white. The heating effect of electricity is also used in electric fires and fan heaters, hair dryers and so on.



Figure 7.12 Uses of electricity in a kitchen.

Electrical power

Figure 7.13 shows two light bulbs connected to a supply of electricity. Both bulbs are converting electrical energy into heat and light. The brighter 100 W bulb is converting 100 J of electrical energy into 100 J of heat and light energy every second. The dimmer 60 W bulb is converting 60 J of electrical energy into 60 J of heat and light energy every second. The 100 W bulb has a higher **power** rating.

Power is measured in joules per second or **watts** (W).

The power (P) of an appliance is related to the voltage (V) across it and the current (I) flowing through it. You will learn more about voltage and current in Chapters 9 and 10.

The equation is:

$$\text{power, } P \text{ (in watts)} = \text{current, } I \text{ (in amps)} \times \text{voltage, } V \text{ (in volts)}$$

$$P = I \times V$$

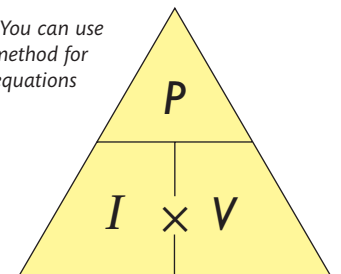


Figure 7.11 The wires inside a toaster have a high resistance and heat up when a current passes through them



Figure 7.13 The 100 W bulb converts more electrical energy into heat and light energy every second.

Figure 7.14 You can use the triangle method for rearranging equations like $P = I \times V$.



Worked example

If an examination question asks for the formula for calculating power, voltage or current, always give the actual equation (such as $P = I \times V$). You may not be awarded a mark if you just draw the triangle.

Example 1

If a 230 V television takes a current of 3 A, calculate its power.

$$P = I \times V$$

$$P = 3 \text{ A} \times 230 \text{ V}$$

$$P = 690 \text{ W}$$

Worked example**Example 2**

Calculate the correct fuse that should be used for a 230 V, 1 kW electric hair dryer (1 kW = 1000 W).

$$P = I \times V$$

$$I = \frac{P}{V}$$

$$I = \frac{1000 \text{ W}}{230 \text{ V}}$$

$$I = 4.3 \text{ A}$$

The correct fuse for this hair dryer is therefore a 5 A fuse.

Calculating the total energy converted by an appliance

The power of an appliance (P) tells you how much energy it converts each second. This means that the total energy (E) converted by an appliance is equal to its power multiplied by the length of time (in seconds) the appliance is being used.

energy, E (in joules) = power, P (in watts) \times time, t (in seconds)

$$E = P \times t$$

since $P = I \times V$

$$E = I \times V \times t$$

Worked example**Example 3**

Calculate the energy converted by a 60 W bulb that is turned on for a) 20 s, and b) 5 min.

a) $E = P \times t$

$$E = 60 \text{ W} \times 20 \text{ s}$$

$$E = 1200 \text{ J or } 1.2 \text{ kJ}$$

b) $E = P \times t$

$$E = 60 \text{ W} \times 5 \times 60 \text{ s}$$

$$E = 18\,000 \text{ J or } 18 \text{ kJ}$$

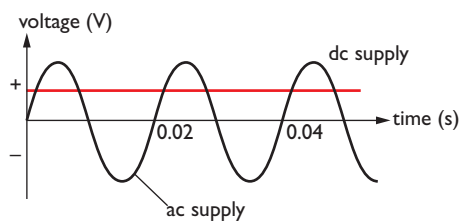


Figure 7.15 How the voltage of an ac supply compares with that of a dc supply.

Alternating current and direct current

The mains electricity supply provides alternating current (ac), which means that the flow of electricity is constantly changing direction. This is because of the way that electricity generators work – you will find out more about this in Chapter 22. Cells and batteries provide direct current (dc), where the current is always in the same direction. Figure 7.15 shows how the voltage of an ac supply compares with a dc supply.

You will need to be able to do the following:

- ✓ realise the dangers of using mains electricity incorrectly
- ✓ understand the steps taken to protect users from electric shocks – for example, use of insulators, earthing, fuses, circuit breakers and double insulation
- ✓ understand that a current can cause an energy transfer and give some examples of domestic uses of the heating effect
- ✓ understand the phrase “power rating” when applied to an electrical appliance and be able to use the equation $P = I \times V$ to determine the correct fuse to use with an appliance
- ✓ use the equation $E = I \times V \times t$ to calculate the total energy transferred by an appliance
- ✓ recall and explain the difference between alternating current (ac) and direct current (dc).

Questions

More questions on domestic electricity can be found at the end of Section B on page 89.

- 1
 - a) A current of 0.25 A flows through a bulb when a voltage of 12 V is applied across it. Calculate the power of the bulb.
 - b) Calculate the voltage that is being applied across a 10 W bulb if a current of 0.2 A flows through it.
 - c) Calculate the current that flows through a 60 W bulb if the voltage across it is 230 V.
 - d) How much energy is transferred if a 100 W bulb is left on for 5 hours?
- 2 An electric kettle is marked “230 V, 1.5 kW”.
 - a) Explain what these figures mean.
 - b) Calculate the correct fuse that should be used.
 - c) Explain why a 230 V, 100 W bulb glows more brightly than a 230 V, 60 W bulb when both are connected to the mains supply.
- 3
 - a) Give one advantage of using a circuit breaker rather than a wire or cartridge fuse.
 - b) Why is the switch for an appliance always placed in the live wire?
 - c) What is meant by the sentence “The hair dryer has double insulation.”?