

How is electricity supply delivered to a house?

The ESB maintains a national network of high tension power lines. The voltages on these lines are as high as 400 kV. Such voltages are not delivered to domestic premises. Instead the voltage is stepped down at *transformers* to a more suitable lower value. A two-wire cable is used to bring electricity to the home. The *neutral* is connected to a metal plate in the ground, and so is at 0V. Therefore, the neutral is said to be *earthed*. The voltage on the live wire alternates to 311V above and below this 50 times a second giving an effective 220V. At the house, a main fuse and meter are installed.

How is electricity distributed in the house?

The cable is then terminated on a *consumer unit*. From the consumer unit different circuits are run to the various points where electricity is needed - lights, sockets, cookers etc. These circuits are all fed with the 220V from the consumer unit, so all domestic circuits are *in parallel*.

The live wire connection to every circuit is fed through a safety device which cuts off the circuit if the current demanded becomes excessive. This can be a *fuse* or a *miniature circuit breaker (mcb)*.



Fig.1 Image of consumer unit and meter

The conductors in the circuit are copper and are *insulated*. The *resistance* must be low enough that,

- at the rated current, the drop in voltage between the consumer unit and the *load* is low
- the copper does not get too hot.

Cables with large diameters have less resistance than those with smaller diameters. In general, domestic circuits are classified as *lighting circuits* or *power circuits*.

How lighting circuits are connected

Two simple lighting circuits are shown below. The first circuit is used where there is a single switch, usually at the door of a room.

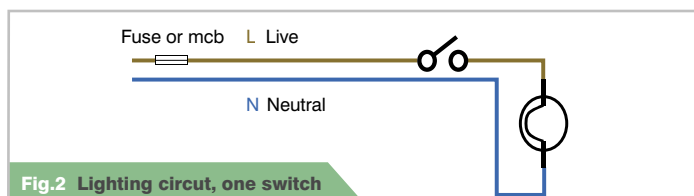


Fig.2 Lighting circuit, one switch

The second circuit is used where there are two switches, for example at each of two doors to a room. The type of switch used is called a *two-way switch* and, if the light is off, as drawn, either switch will switch it on. If the light is on, either switch can switch it off. Examine the circuit and see why this is so.

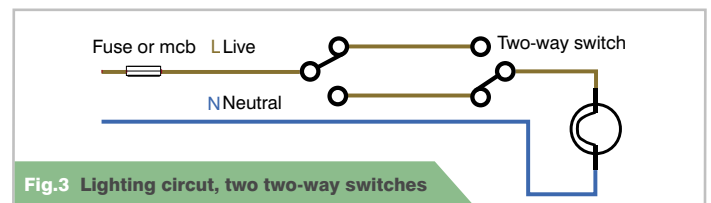


Fig.3 Lighting circuit, two two-way switches

Lighting circuits do not require large currents. Typically, a circuit breaker or fuse of 6 amps is used. The conductors in lighting cables therefore need not be very thick. One 100 Watt bulb uses less than half an amp as shown below.

$$IV = \text{Power} \quad 0.45 \text{ A} \times 220\text{V} = 100 \text{ W}$$

Therefore, a 6 amp mcb could safely protect a circuit feeding more than ten 100 W bulbs. In practice, the lighting circuits for a number of rooms are connected in parallel and supplied through one mcb. It is not convenient to have all lights fail at the same time so it is common to have two or more lighting circuits in a house.

Power circuits for appliances (sockets)

The term *appliance* is a general term for any thing powered through a plug and a flexible cable. The standard plug is designed to carry up to 13 amps, though most appliances need considerably less. Inside the plug there is a fuse. The fuse is usually either a 3-amp fuse (for appliances up to 660 Watts) or a 13-amp fuse (for appliances up to almost 3 kilowatts). Where a 3-amp fuse is sufficient it should be used. A fault then is more likely to blow this fuse only, rather than both blow it and also trip the mcb on the consumer unit.

In general, almost all the power consumed in a house is converted into heat. Appliances that generate a lot of heat, like electric fires or kettles, use large currents and consume a lot of power. At 220V, the current per kilowatt is about 4.5 amps. Many other appliances such as radios or mobile phone chargers need little power.

When sockets are fitted as shown below, the circuit is called a *radial* circuit. (It radiates out from the consumer unit.) Because each socket can supply 13 amps there is a limit to the number of sockets that can be supplied by one cable.

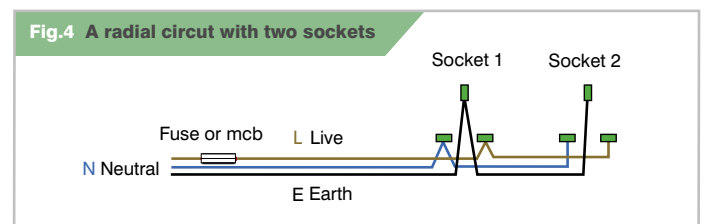
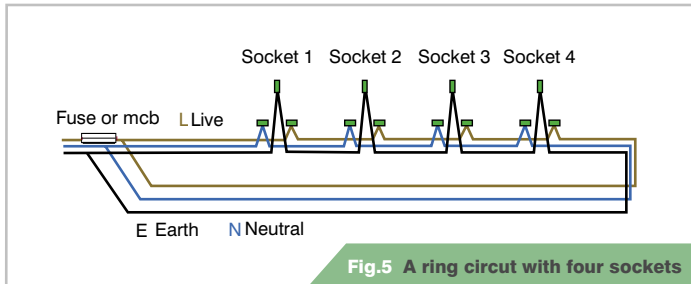


Fig.4 A radial circuit with two sockets

An alternative approach is the *ring* circuit. Here the circuit takes the form of a ring with both ends of the ring connected to the consumer unit. Both "live" wires are connected to one mcb, both neutrals to the neutral, both earths to earth. This has the advantage that the current demanded can flow two ways and is spread over two conductors. A ring circuit can contain more sockets than two radial circuits.



Other circuits

Other types of domestic load use large currents and are supplied by independent radial circuits which are not connected to any other appliance. The most common are immersion (water) heaters, cookers and electric showers. Cookers and showers require very thick conductors.

Why use fuses and mcbs?

A fuse is a wire that will get hot and melt ("blow") if the circuit is above its rated current. By melting, the fuse disconnects the live wire from the load, reducing the risk of overheating and fire.

Like a fuse, a miniature circuit breaker disconnects the live wire if the current is too large. It is a switch with contacts that open very quickly. Circuit breakers are faster and more precise than fuses and they can be reset. The circuit breakers on a distribution board are very compact and are called *miniature circuit breakers*.

What is a residual current device (RCD)?

One device that reduces the likelihood of harm from electric shock is the RCD. Electricity enters and leaves a house through the live and neutral wires. Normally, the amount of electricity entering is matched by exactly the same amount leaving. If there is a fault however, it often involves some electricity from a live wire going to earth, possibly through a person. This is called a *residual current* or an *earth-leakage current*.

A fault current to earth has implications. Even 100 mA can cause a fire. An even smaller current, 30 mA, can kill a person.

The RCD consists of a circuit breaker which is tripped if the currents entering and leaving on the live and neutral wires differ by more than 30 mA. Domestic RCDs will usually also trip if a certain current, for example 63 A, is exceeded.

The current for most or all of the circuits in modern houses is fed via an RCD which is between the main fuse and their mcbs or fuses.

What is the earth rod?

The earth wire in a domestic circuit is connected to an earth *electrode* in the ground which provides a low-resistance path via the ground itself to the transformer. At the transformer, the neutral is connected to a plate in the ground. This is why electricity will flow from live to earth.

What is ESB Customer Supply?

ESB Customer Supply supplies electricity to 1.8 million customers (on the basis of published tariffs). It provides customers with services which meet their needs (for example, budget accounts, direct debit and other payment options) and with appropriate advice to help them use electricity more efficiently while saving money at the same time.

ESB Customer Supply employs approximately 650 people and in any one year issues 11 million bills and handles over 3 million telephone calls from customers.

As a business unit within ESB, Customer Supply has over 75 years experience in providing electricity services to customers throughout Ireland.

Ireland has one of the fastest-growing electricity markets in the developed world. It grew over 40 per cent over the last 10 years, far ahead of average growth in the rest of Europe. The market has been fully opened to competition since February 2005.

You can find out more about ESB Customer Supply by logging onto www.esb.ie and www.sciencetechnologyaction.com

Be careful with electricity

'Electricity is so much a part of modern living that we can often take it for granted. It is a powerful and versatile energy but can be dangerous if not used properly.'

Serious accidents with electricity in the home are rare but each year there is a small number of fatalities and serious injuries. Most of the accidents that occur are due either to carelessness or to a lack of awareness of some basic rules that should always be observed when using electricity.'

The above is an extract from the booklet *The Safe Use of Electricity in the Home* which is produced by the ESB in cooperation with the Electro Technical Council of Ireland. The booklet contains essential information on electrical safety in general and also hints and rules which you should always follow.

The booklet is available on www.esb.ie.



Syllabus Reference

Leaving Certificate Physics:

Electricity 7, Domestic circuits

Junior Certificate Science:

Section 3C5, Electricity in the home

Learning Objectives

On completing this section, the student should be able to:

- Describe the ideas behind electricity distribution and use in the home
- Outline some safety aspects of using electricity
- Identify different types of circuits and protective devices
- State the formula relating power, voltage and current

General Learning Points

- Small electric currents can kill.
- People conduct electricity. A typical person has a resistance of between $1.5 \text{ k}\Omega$ and $5 \text{ k}\Omega$. It varies with the individual and whether the skin is wet or not.
- Even a current as low as 7 mA can prevent the victim from letting go.
- For a resistance of $1.5 \text{ k}\Omega$ the current would be about 150 mA and from arm to arm through the heart. This is likely to be fatal.
- Fuses do not protect people from shocks, the current required to kill a person is much lower than the rating of any household fuse.
- For simplicity, no earth wire was shown in the lighting circuits but metal light fittings must be earthed.
- Most electricity is converted into heat. Where a lot of heat is generated, a lot of electricity (energy) is consumed.
- 220 V is an effective mean, the peak voltage is 311 V ($220 \times \sqrt{2}$) because the neutral is earthed it is at 0 V .

Activities

- Energy saving devices make sense, look at the difference in running costs for a CF and incandescent bulb.
- If you are watching the light from a lamp when a kettle, or something else, is also switched on, a small reduction in brightness may be seen. Ohm's law says that if the current through a resistance increases the voltage across it increases. It seems strange to think of the conductors as a resistance but they are and the 220 V supply in the house is reduced by the voltage drop caused by the extra current.
- In the 1950s, it was common for a rural house with electricity to have electric lights, one socket and, possibly an electric cooker. How has life changed in the last 50 years? How many sockets are there in your home?
- Consider the second lighting circuit which has two two-way switches. If a third (or even a fourth or fifth) switch is required, this is possible by inserting a different type of switch in the circuit between the two-way switches. This switch is called an intermediate switch. It has four terminals. You can insert as many as you wish. Can you guess what an intermediate switch does?
- Check the cable attached to an appliance. It usually has three wires. These are coloured *brown*, *blue* and *green/yellow*. Looking into the plug when the back is taken off, there are three pins and a cord grip visible. The green yellow earth wire is connected to the pin in the top centre. The neutral wire is blue and connected to the pin on the left (normally marked "N"). The pin on the right is the live pin and it is connected to a fuse. The other end of the fuse (normally marked "L") is connected to the brown live wire. When wiring a plug it is important that the cord grip grips the outer sheath and not just the wires. Some appliances only have two wires, brown and blue. Connect them as above.

True or False

Indicate whether the following are true (T) or false (F) by drawing a circle around T or F.

- | | | |
|--|---|---|
| (a) Fuses protect people from shocks | T | F |
| (b) Your electricity bill charges for the total voltage you have used | T | F |
| (c) The green/yellow wire in a plug goes to the earth pin at the top | T | F |
| (d) A two-way switch is needed to light two bulbs at the same time | T | F |
| (e) A 6A fuse can cater for 10 100W bulbs | T | F |
| (f) People are good insulators | T | F |
| (g) When switched on, a kettle uses less electricity than a 100W bulb (the bulb is obviously much hotter). | T | F |
| (h) All domestic circuits are in series | T | F |
| (i) Modern supplies will cut off if an earth-leakage of 50 mA is detected | T | F |
| (j) The fuse in a plug is in series with the live wire | T | F |
| (k) A 6A fuse can cater for a 2.5 kW kettle | T | F |
| (l) Big fuses are best because they blow less often | T | F |

Check your answers to these questions on www.sciencetechnologyaction.com



Examination Questions

2004 Higher Level

Read the following passage and answer the following questions.

Your home is supplied with electricity at 230 volts, 50 Hertz. At the electrical supply intake position is your main consumer unit or fuse board. At the position you will find your main switch. Your sockets, immersion group and bathroom heater (or shower) are protected by Residual Current Devices (RCD) installed in your fuse board. These provide a high degree of safety on these circuits and it is important that they are tested at least every 3 months. The final circuits are protected by Miniature Circuit Breakers.

It is advisable to contact your local ESB about cheaper night tariffs, these could make significant savings to your electricity bill. Storage heaters may be used to avail of these cheaper rates.

Each plug top contains a small cartridge fuse. Cartridge fuses are supplied with a rating of 1A, 2A, 3A, 5A and 13A. A fuse should never be replaced by anything other than a suitable fuse.

(Adapted from 'Home Safety', Register of Electrical Contractors of Ireland. RECI)

- Name and give the colour of the wire that should be connected to the fuse in a standard three-pin plug. (7)
- Explain why replacing a fuse with a piece of aluminium foil is dangerous. (7)
- A table lamp has a power rating of 100W. What is the most suitable fuse for the lamp? (7)
- Some electrical appliances are supplied with two-pin plugs. Why is the earth wire not required in these devices? (7)
- Sketch a voltage-time graph of the 230V supply. (7)
- Explain how a Residual Current Device (RCD) operates. (7)
- Give one advantage of a Residual Current Device (RCD) over a Miniature Circuit Breaker. (MCB) (7)
- Storage heaters have a large heat capacity. Why? (7)

For further examples of past paper exam questions check out www.sciencetechnologyaction.com

Did You Know?

- When the State was founded in 1922, hundreds of small electricity schemes existed. These provided limited electricity supply in cities and towns.
- There was also a proposal to dam the river Shannon near Limerick and build a hydro-electric electricity station. The government appointed Siemens, a German engineering firm, to provide a detailed scheme for this. The work was started in 1925.
- This was a giant project and associated with it was a vision of a properly planned and organised electricity supply needed for the development of the new State.
- Legislation was passed to create the organisation to do this and the ESB was formed in 1927. It gradually took over the major existing suppliers and created an essential national electricity supply body.

Biographical Notes

Alessandro Volta

an Italian physicist famous as a pioneer in electricity. He was professor of physics at the Royal School in Como and then at the University of Pavia. He invented the electrophorus in 1775, an instrument that produced charges of static electricity. He also developed the voltaic pile, a type of battery. In honour of his work, Napoleon made him a Count in 1810.

Georg Simon Ohm

was a German physicist, whilst working as a high school teacher, started his research with the recently invented electrochemical cell, invented by Italian Count Alessandro Volta. Using equipment of his own creation, Ohm determined that the current that flows through a wire is proportional to its cross sectional area and inversely proportional to its length. This is Ohm's law and can be written as $V = IR$ where V is voltage, I is current and R is resistance.

Andre Marie Ampere

a French physicist, is best known for defining a way to measure the flow of current, which was named after him, the ampere. He also laid the foundation for the science of electrodynamics. Among his accomplishments was figuring out a way to measure the strength of a magnetic field in relation to an electric current, known as Ampere's theorem. Ampere's law is a rule that deals with the mutual interaction of current-carrying wires.

You can find out more about these and other great scientists at www.sciencetechnologyaction.com

Revise the Terms

Can you recall the meaning of these terms? Revising the terminology is a powerful aid for recall and retention.

Transformers; neutral; earthed; live; consumer unit; parallel; fuse; miniature circuit breaker (mcb); insulated; resistance; load; lighting circuits; power circuits; two-way switch; appliance; radial; ring; residual current; earth-leakage current; electrode

Check the Glossary of Terms for this lesson at www.sciencetechnologyaction.com