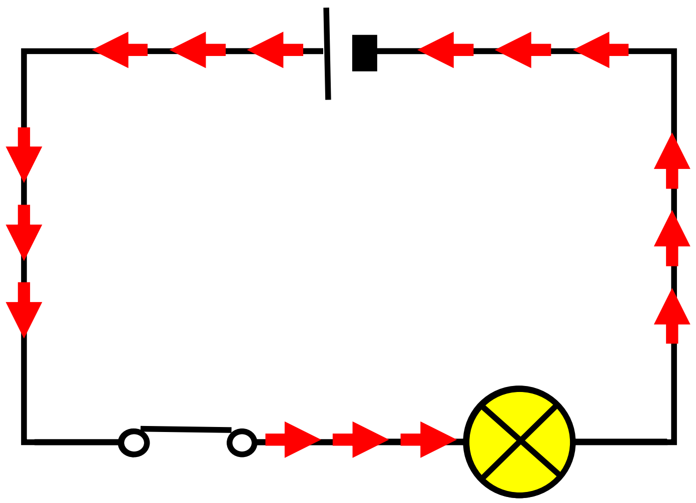
Mains Electricity

Year 11 Physics Term 4 Week 1

Direct current

Cells and batteries supply electric current which always flows **in the same direction**.

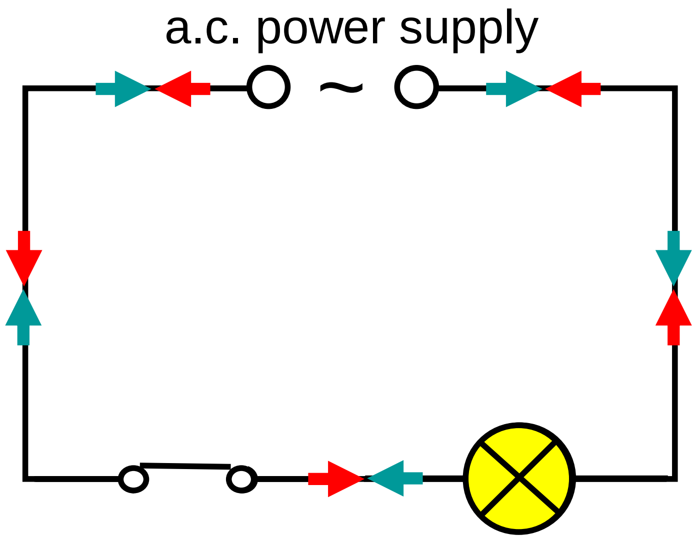
This is called **direct current (d.c.).**



Direct current always flows the same way

Alternating current

An **alternating current (a.c.)** is one which is constantly **changing direction**.



Alternating current constantly changes direction.

The lamp works with a.c. and d.c.

Mains Electricity

The electricity supplied to our homes is called **Mains Electricity.**

It is an alternating current supply.

In the Australia the current changes direction every $1/100^{th}$ of a second.

This means it completes a complete cycle of changes every $1/50^{th}$ of a second.

It therefore has a **frequency** of 50 cycles per second
or **50 hertz** (50 Hz).

How electricity arrives into our homes

The **LIVE** and **NEUTRAL** terminals

Mains supply is rated at about 230 volts.

This means that it has the same effect as a 230V d.c. battery on devices like a lamp.

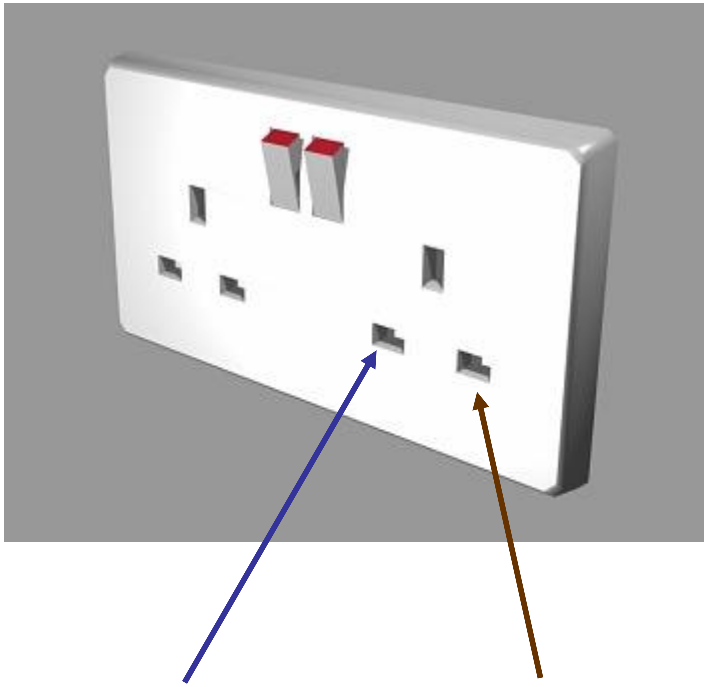
One side of the a.c. supply changes constantly between +325V and – 325V.

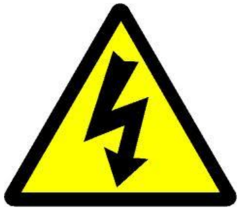
This terminal is called the LIVE.

Touching this terminal can be **fatal!**

The other terminal remains at about 0V.

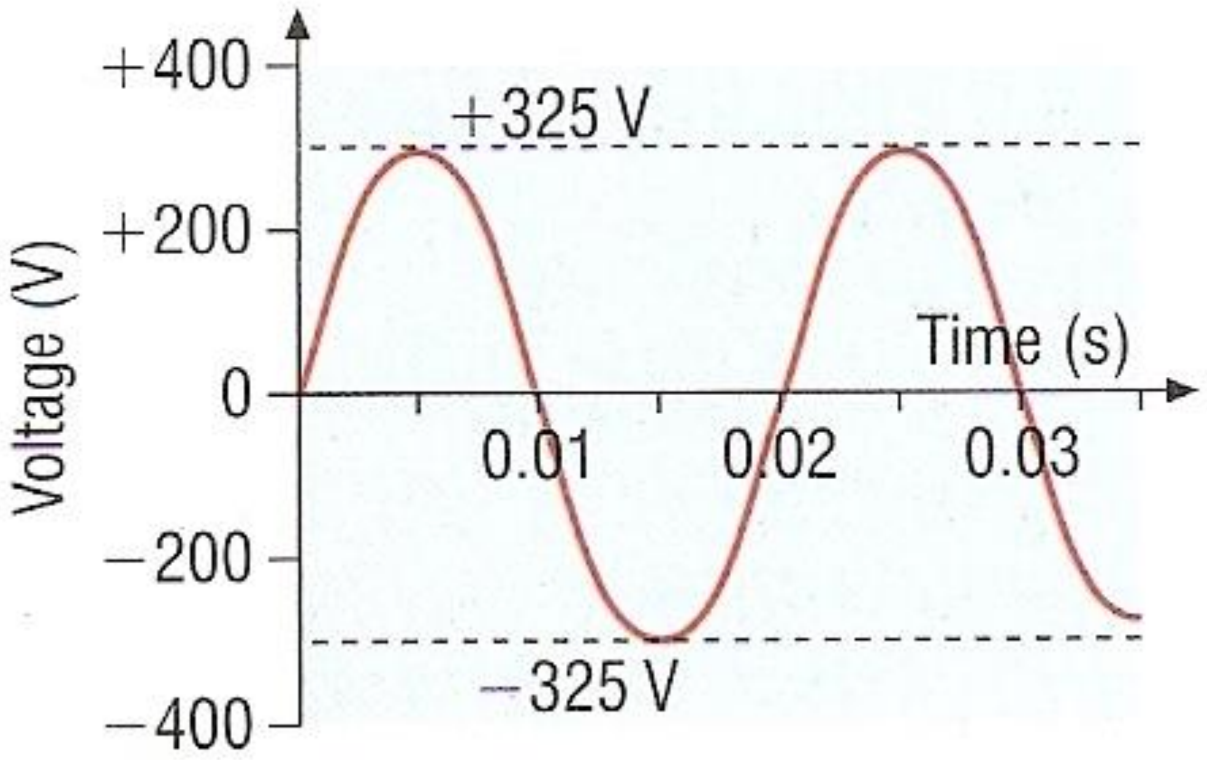
This terminal is called the NEUTRAL.





Voltage variation of the **LIVE** terminal

The voltage of the **LIVE** terminal varies **SINUSOIDALLY** between +325V and – 325V taking 1/50th or 0.02 second to complete one complete cycle.



Choose appropriate words to fill in the gaps below:

__Direct__ current (d.c.) is a current that always flows in __one__ direction around a circuit. It is supplied by cells and __batteries__.

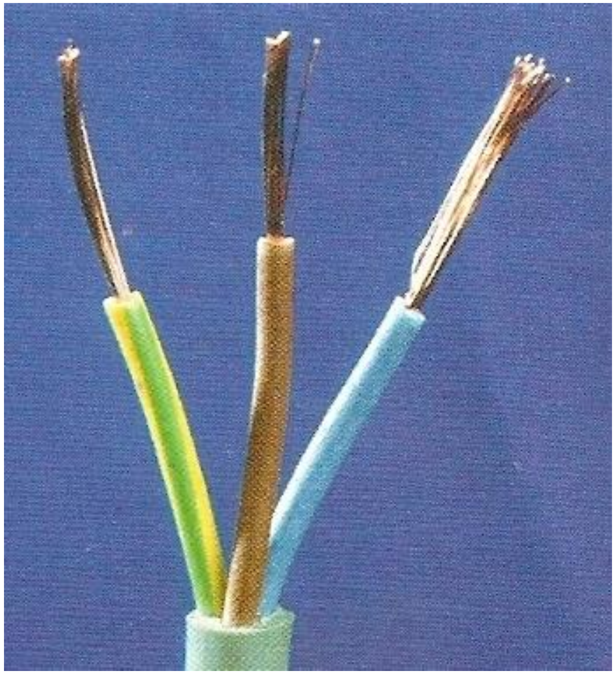
Alternating current (a.c.) constantly __reverses__ in direction. The __mains__ supply to our homes is a.c. In this case the a.c. is supplied at an effective voltage of __230V__ and a frequency of __50Hz__.

An __oscilloscope__ can be used to display and __measure__ a d.c. or a.c. waveform.

WORD SELECTION:

batteries mains one 50Hz measure
Direct 230V oscilloscope reverses

Electrical cable



Electrical cable consists of:

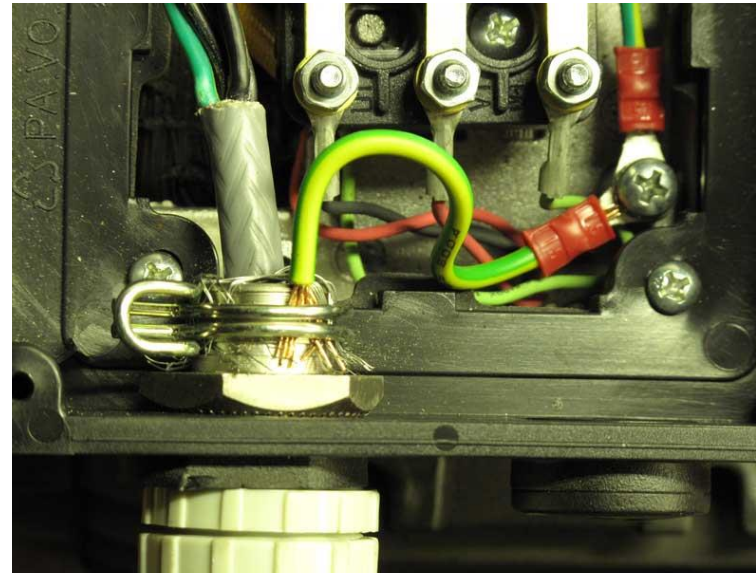
1. A **LIVE** wire
   with **BROWN** insulation
2. A **NEUTRAL** wire
   with **BLUE** insulation

and except with some devices with plastic cases

3. An **EARTH** wire
   with **YELLOW-GREEN** striped insulation.

These are all surrounded by an outer layer made of rubber or flexible plastic.

The **EARTH** wire



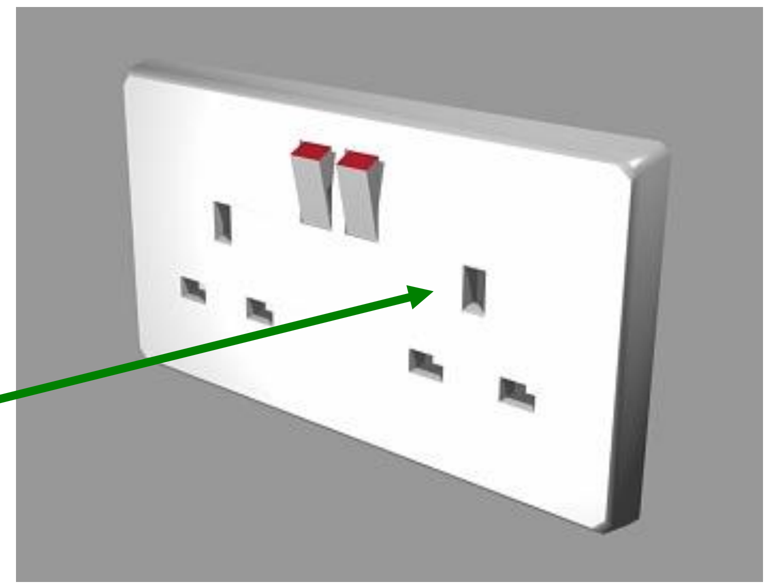
This is a safety feature.

The earth wire is connected to the metal casing of a device.

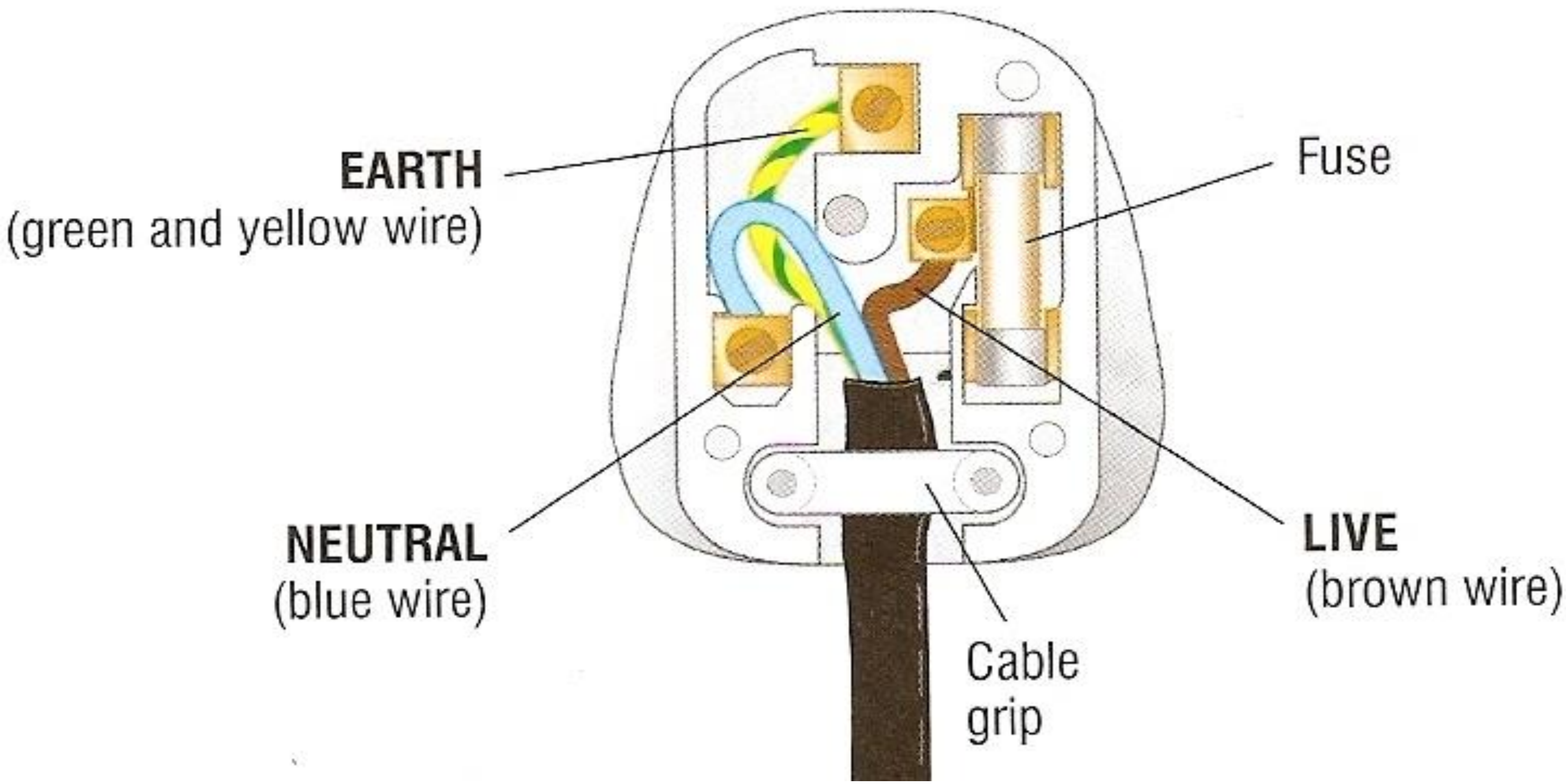
The other end of this wire is connected to a metal rod or pipe that goes into the ground below a building.

Appliances that have plastic cases, for example hairdryers, do not need the earth wire connection.

EARTH

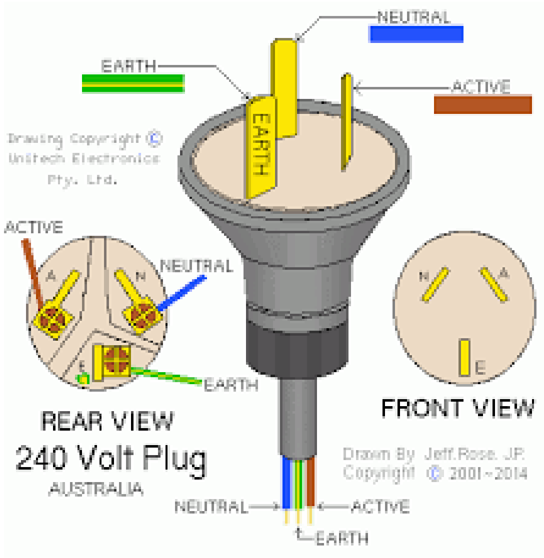


The three pin plug



Materials used in plugs, sockets and wires

BRASS – Hard rigid metal and electrical conductor
– used for plug pins and socket terminals

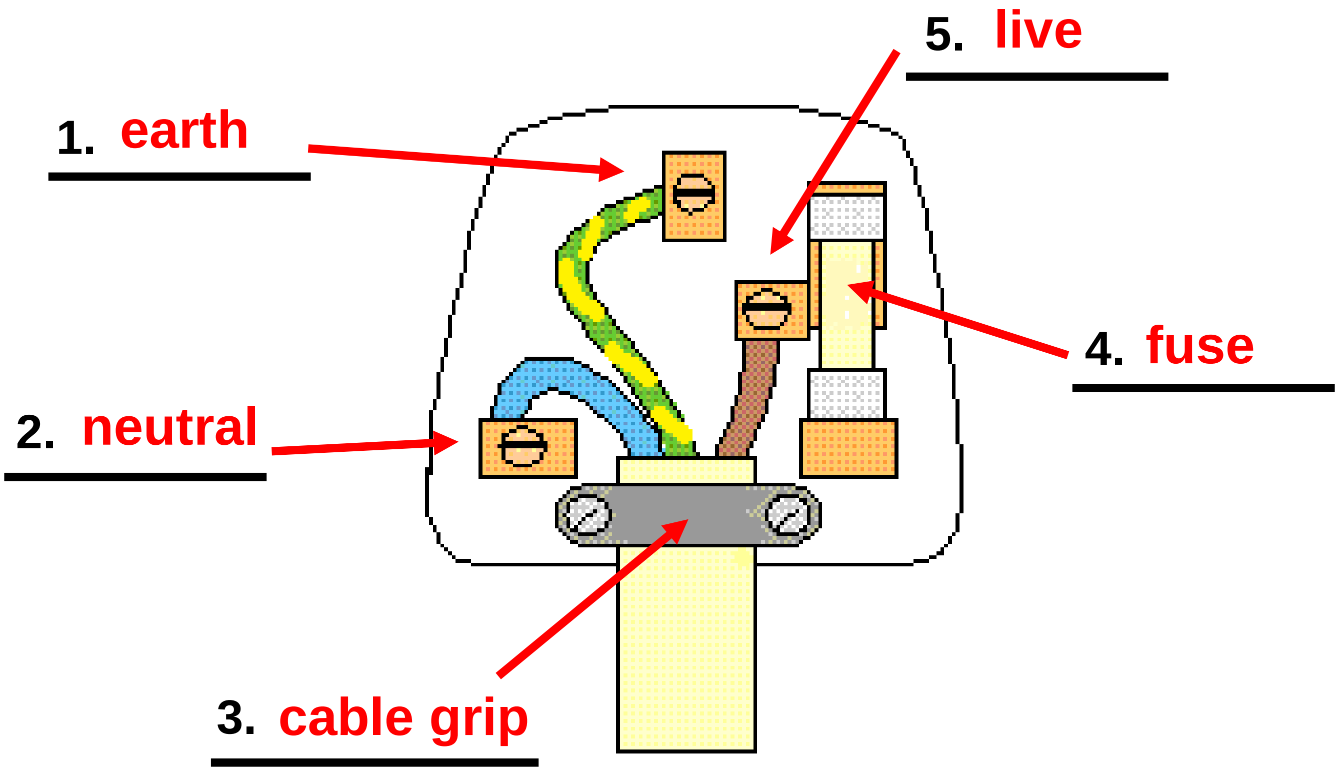


COPPER – Flexible electrical conductor
– used for the wires

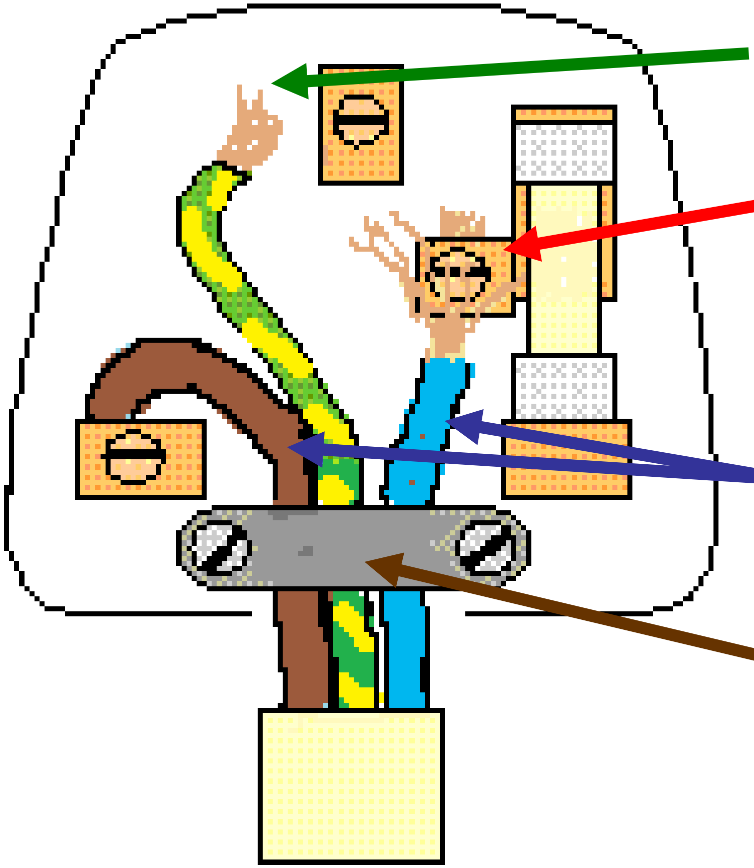
PLASTIC – Hard rigid electrical insulator
– used to make the plug and socket

RUBBER – Soft flexible electrical insulator
– used for wire insulation

Label this diagram



What is wrong with this plug's wiring?



Earth wire not connected

Wire untidily connected – some bare strands of wire showing

Live and neutral wires swopped over

Cable grip not gripping the outer plastic insulator

Note: The appliance connected with this plug would probably still work but it would be very dangerous to use!

Choose appropriate words to fill in the gaps below:

Most electrical cables contain __three__ separately insulated wires. __two__-core cables are only used with appliances that have __plastic__ casings.

The live wire has __brown__ insulation, the neutral has __blue__and the __earth__ has striped yellow-green.

In a 3-pin plug the live is connected on the __right__ next to the fuse. The neutral is on the __left__and the earth is connected at the top.

WORD SELECTION:

plastic earth right left two brown three blue

The Dangers of Mains Electricity

The two main dangers of mains electricity are:

1. FIRE

This can be caused by too high a current flowing along cables or through appliances.

A fuse or circuit breaker is used to limit the current to a safe level.

2. ELECTROCUTION

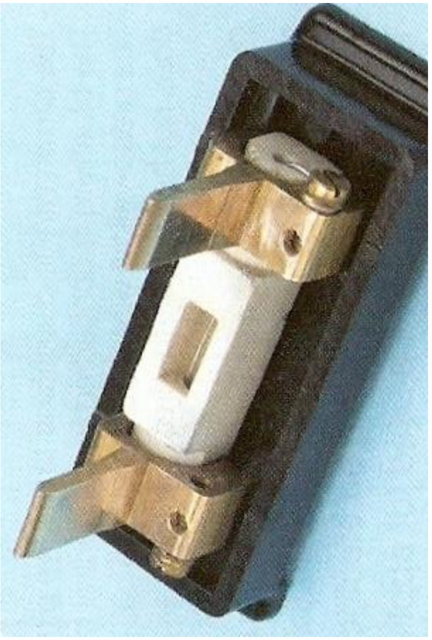
This can occur when contact is made with the **LIVE** wire. Death can occur if a current above about 100mA (0.1A) flows through the body.

The **EARTH** wire in combination with a fuse or circuit breaker can prevent electrocution.

Fuses

A fuse is a length of wire designed to **melt** and so breaking a circuit when the **current** passing through it goes above a certain level.

Fuse wires



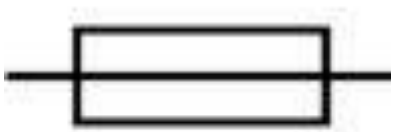
Cartridge used with fuse wire

Internal fuse from an appliance

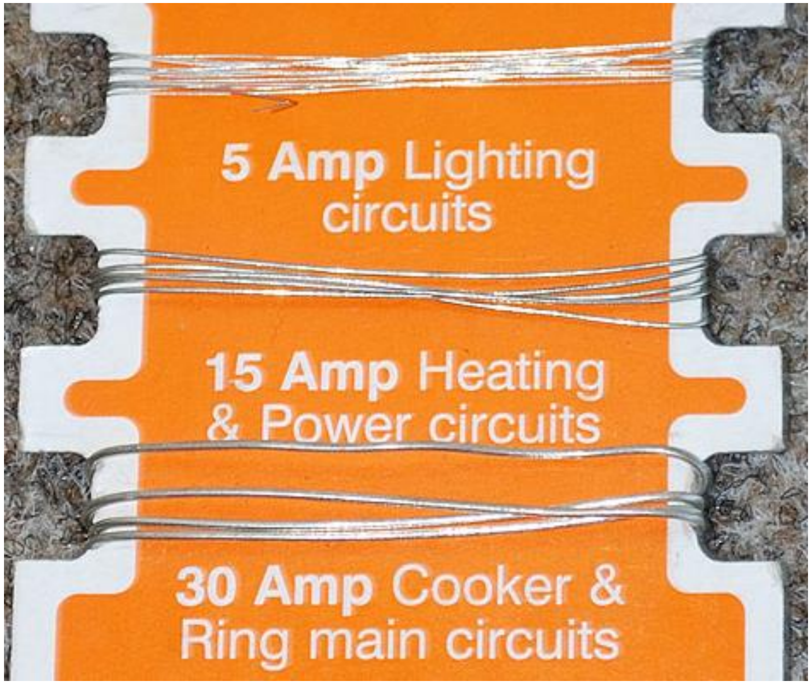
3A, 5A and 13A fuses used in 3-pin plugs

The **thicker** the fuse wire the **greater** is the current required to cause it to melt (or fuse).

Fuses are only supplied with a limited number of ratings.



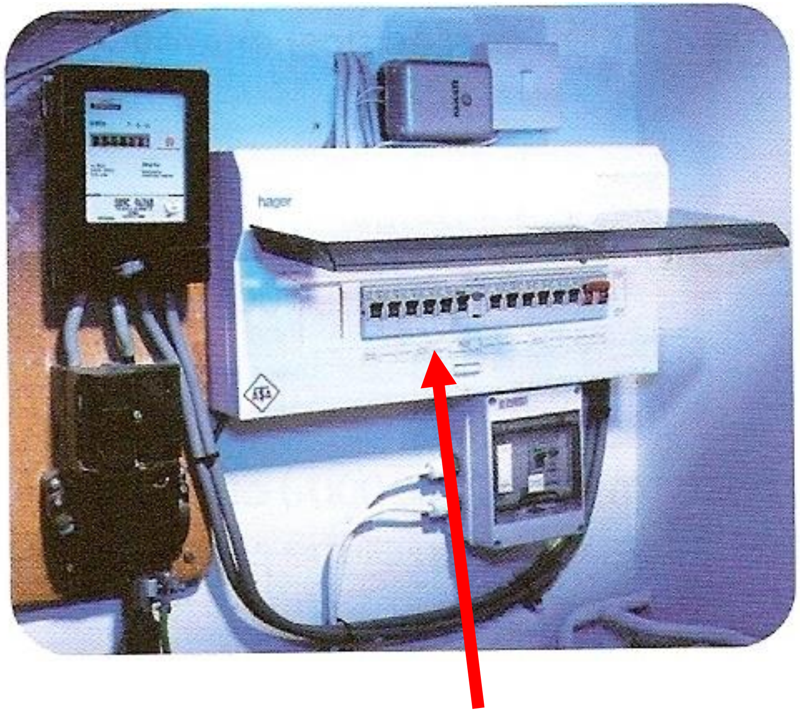
Modern circuit symbol for a fuse



Circuit Breakers

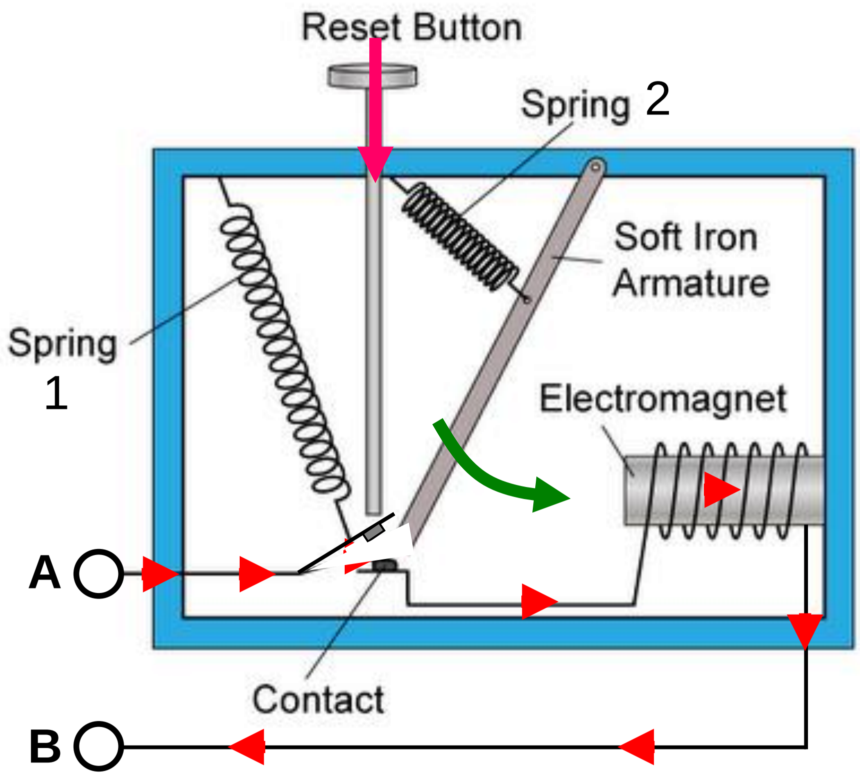
A circuit breaker is an electromagnetic device that breaks a circuit when the current goes above a certain value.

RCD (Residual Current Device) circuit breaker used with an individual appliance



Circuit breakers in a consumer unit

A simple circuit breaker



Current normally flows between terminals **A** and **B** through the contact and the electromagnet.

When the current in a circuit increases, the strength of the electromagnet will also increase. This will pull the soft iron armature towards the electromagnet.

As a result, spring 1 pulls apart the contact and disconnecting the circuit immediately, and stopping current flow.

The reset button can be pushed to bring the contact back to its original position to reconnect the circuit

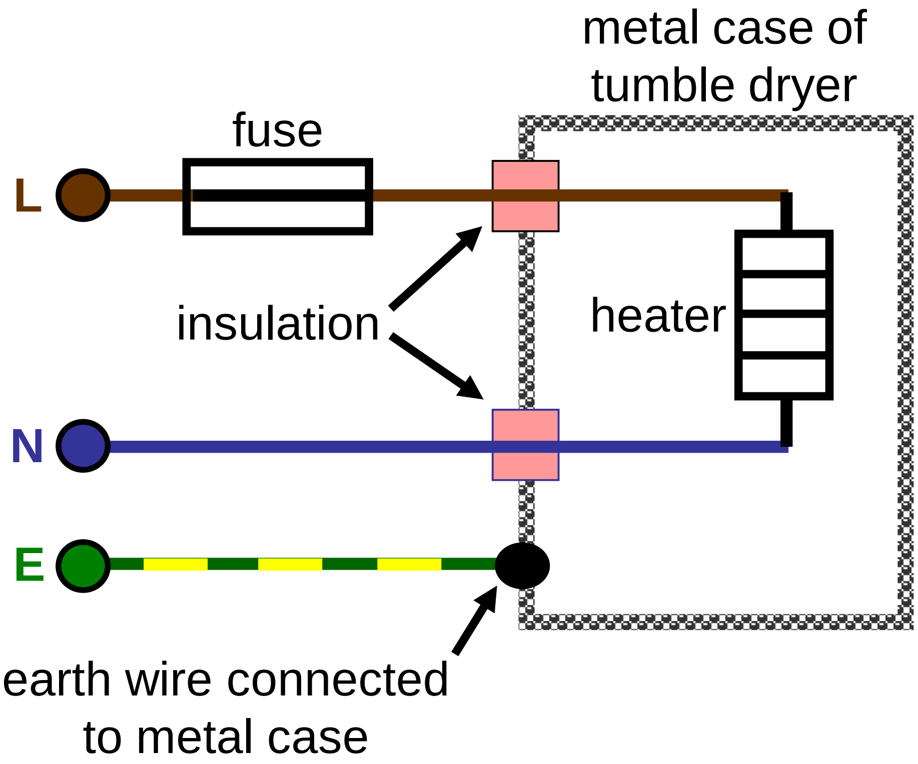
Comparison of fuses and circuit breakers

Both can prevent fire by limiting the current flowing through a cable or appliance.

Fuses are simple and are cheap to replace.

Circuit breakers act more quickly than fuses and can be reset.

The action of the **EARTH** wire

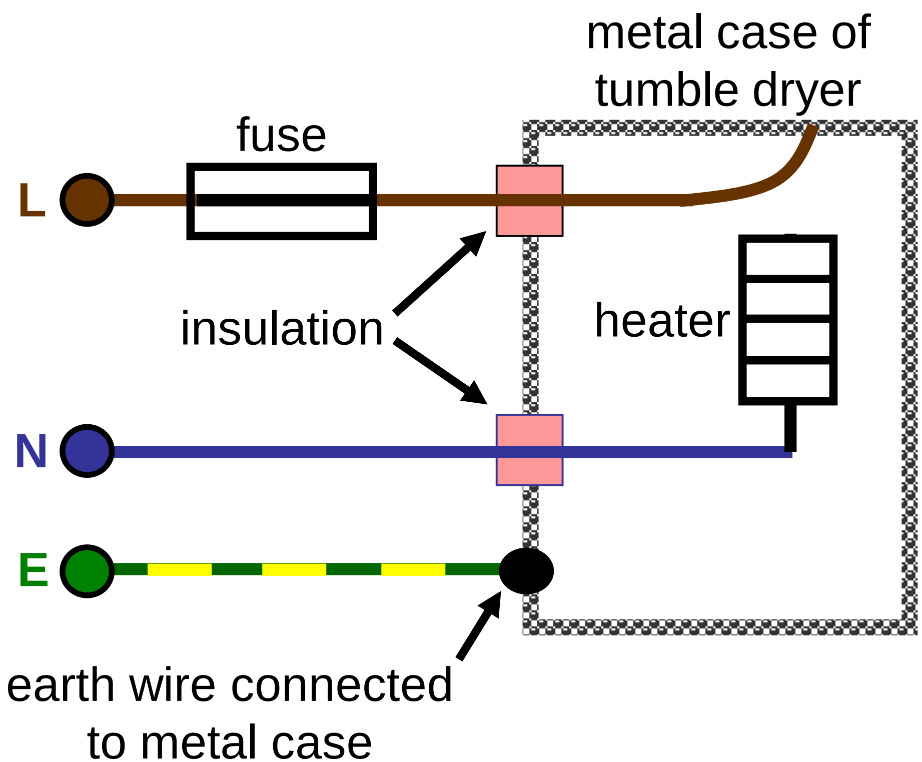


Appliances with metal cases such as a tumble dryer are usually earthed by having the **EARTH** wire connected to their metal case.

Normally current flows to and fro between the **LIVE** and **NEUTRAL** wires through the heater of the dryer.

The metal case is at zero volts and is safe to touch.

The action of the EARTH wire

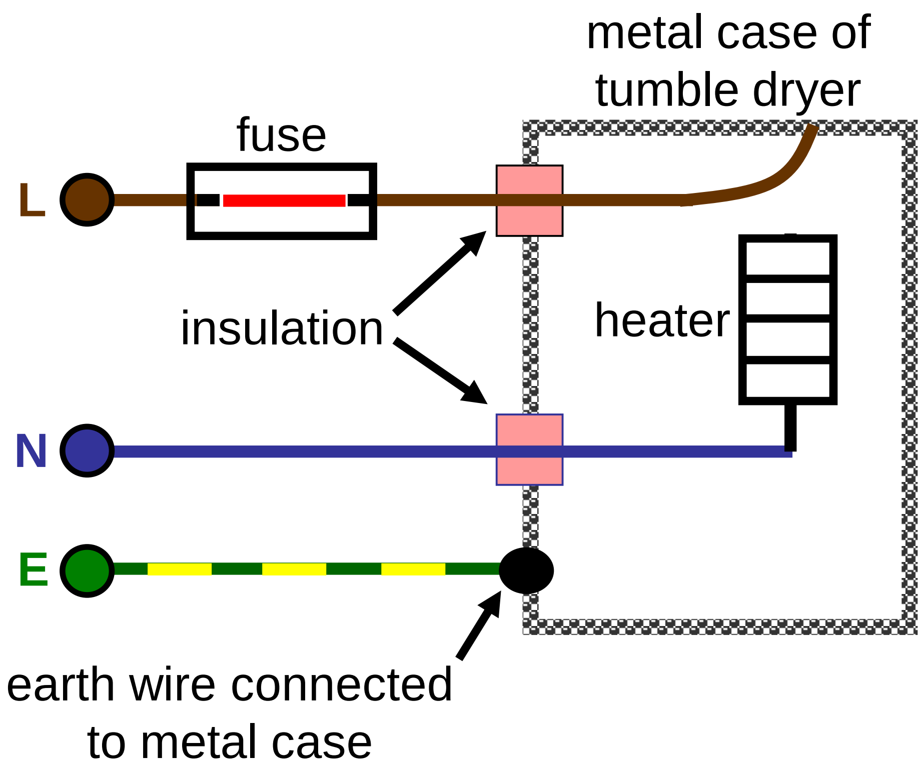


If the **LIVE** wire became loose inside the dryer it might touch the metal case.

The metal case would now be dangerous to touch and could give a fatal electric shock.

However, the **EARTH** wire provides a low resistance path to the ground.

The action of the **EARTH** wire



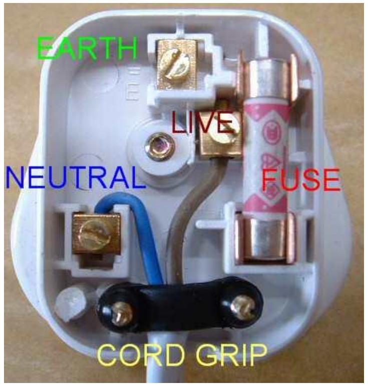
A large current now flows through the **fuse** and causes it to melt.

The dryer's metal casing is now isolated from the **LIVE** connection and is safe to touch.

Double insulation

Many electrical appliances have casings made from an insulator such as plastic rather than metal. The electrical parts of the device cannot therefore be touched by the user.

The appliance is said to have **double insulation**. Such appliances will only have two-wire cables as they do not need the EARTH wire.

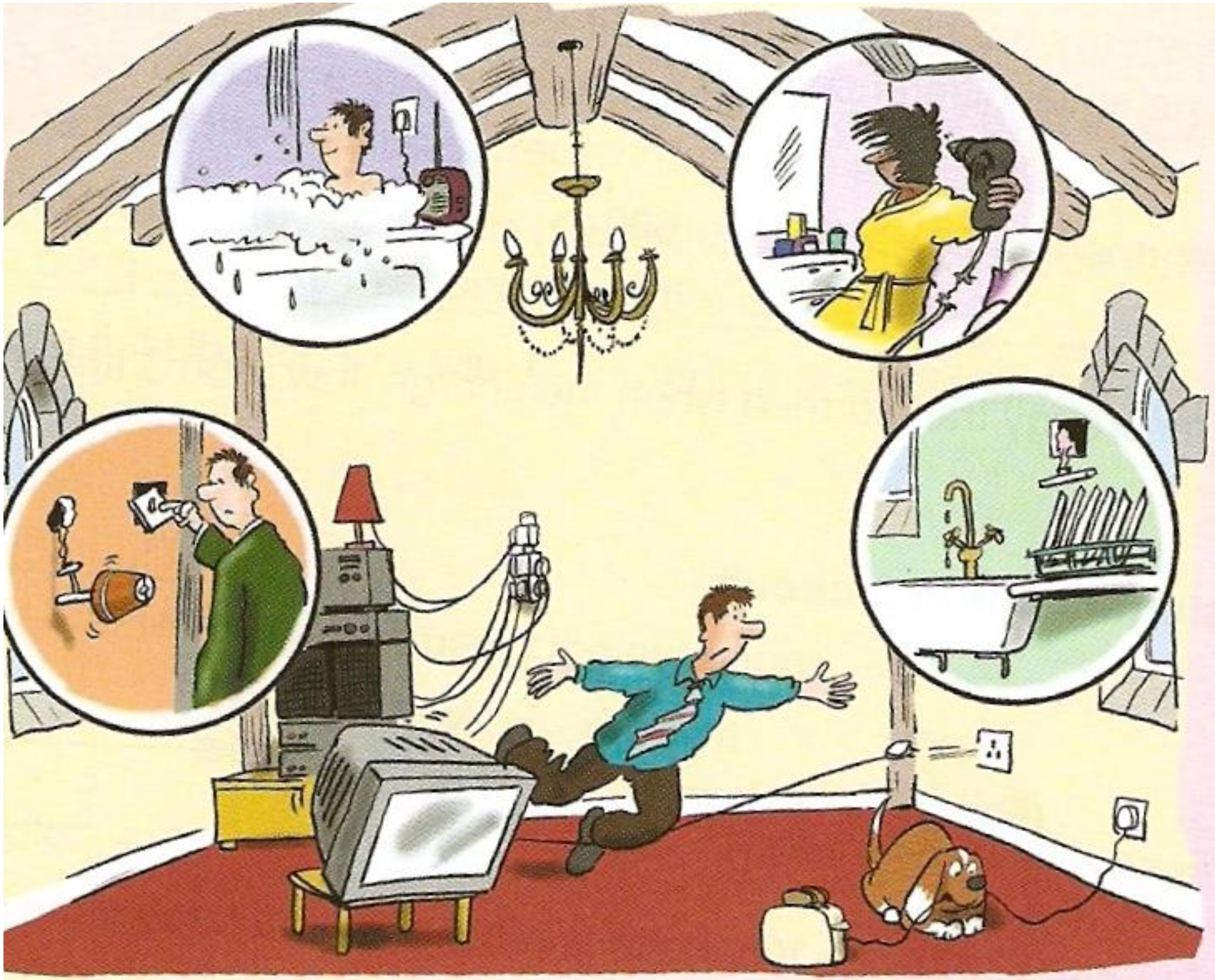


Plug wiring for a device with double insulation

Plastic cased food mixer will have double insulation

Symbol found on devices having double insulation

How many dangerous practices can you spot in the picture below?



Choose appropriate words to fill in the gaps below:

Two dangers of mains electricity are _fire_ and electrocution.

Fires are caused when too high a _current_ is allowed to flow along cables. Current can be limited by placing a _fuse_ or circuit breaker in the _live_ wire.

The _earth_ wire is used to prevent the metal casing of an appliance from becoming live should a wiring fault occur. A _large_ current flowing down the earth wire will cause the fuse or circuit breaker to _isolate_ the live connection.

WORD SELECTION:

current earth live fire isolate large fuse

The heating effect of an electric current

House wiring is made of copper wire and is designed to let electric current flow through it easily. It is said to have a low **resistance**.

However, the parts of some devices such as the heating elements of kettles and toasters are designed to have a high **resistance**.

Resistance causes **heat energy** to be produced when an electric current flows.

The greater the resistance and current the hotter the heating element may become.

A kettle's heating element

Electrical power (***P***)

The electrical power, ***P*** of a device is equal to the rate at which it transforms energy from electrical to some other form (such as heat).

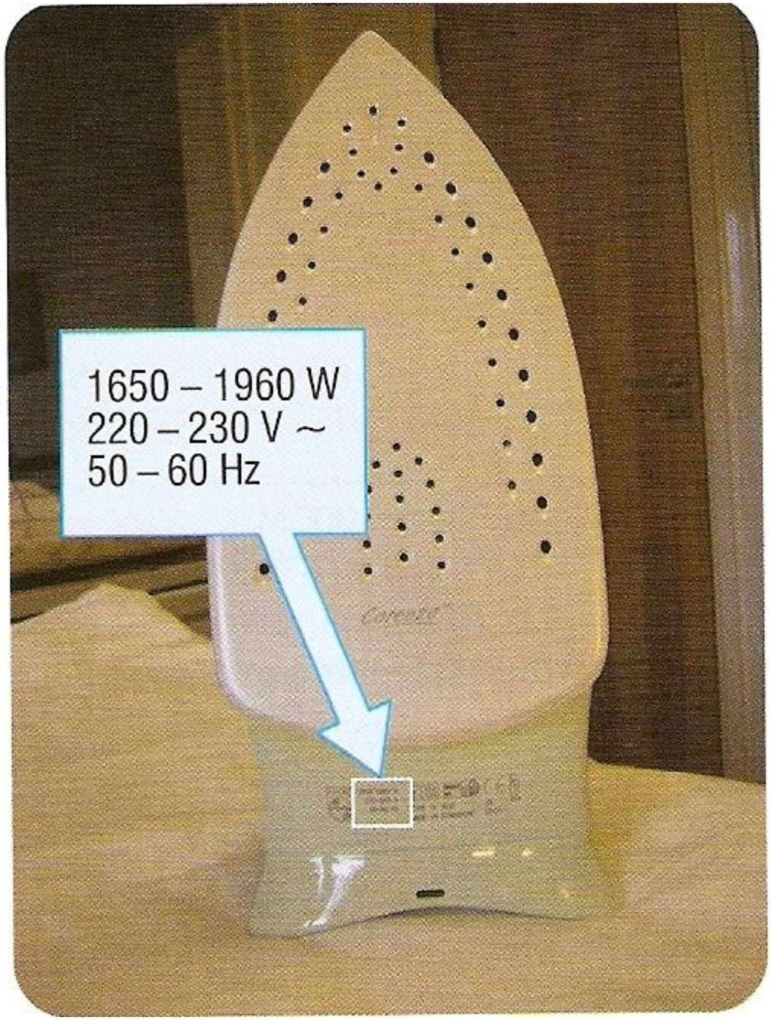
electrical power = energy transferred ÷ time

electrical power is measured in **watts (W)**
energy in **joules (J)**
time in **seconds (s)**

also:
1 kilowatt (kW) = 1 000 watts
1 megawatt (MW) = 1 000 000 watts

Electrical power ratings

These are always shown on an electrical device along with voltage and frequency requirements.



Electrical power examples

Device	Power rating
Torch	1W
Energy efficient lamp	11 W
Desktop computer	300 W
Hairdryer	1 000 W or 1 kW
Electric kettle	2 000 W or 2 kW
Electric shower	5 kW

Question 1

Calculate the power of a light bulb that uses 1800 joules of electrical energy in 90 seconds.

electrical power = $\dfrac{\text{electrical energy}}{\text{time}}$

= $\dfrac{1800\ \text{J}}{90\ \text{s}}$

electrical power = 20 watts

Question 2

Calculate the energy used in joules by a heater of power 3kW in 1 hour.

electrical power = <u>electrical energy</u>

time

becomes:

electrical energy = power x time

= 3 kW x 1 hour

= 3000 W x 3600 seconds

electrical energy used = 10 800 000 joules (or 10.8 MJ)

Answers

Electrical energy used	***Time***	***Power***
600 J	20 s	**30 W**
7 500 J	15 s	500 W
800 J	**40 s**	20 W
60 kJ	10 minutes	**100 W**

Electrical power, *P* electric current, *I* and voltage *V*

electrical power = current × voltage

$$P = I \times V$$

electrical power is measured in **watts (W)**

electric current in **amperes (A)**

voltage in **volts (V)**

Question 1

Calculate the power of a 230V television that draws a current of 2.5A.

electrical power = current × voltage

= 2.5A x 230V

power = 575W

Question 2

Calculate the current drawn by a kettle of power 2kW when connected to the mains 230V power supply.

P* = *I* x *V

becomes:

I* = *P* ÷ *V

= 2kW ÷ 230V

= 2000W ÷ 230V

electric current = 8.7A

Answers

I	*V*	*P*
5 A	230 V	**1150 W**
2 A	230 V	460 W
4 A	**12 V**	48 W
200 mA	6 V	**1.2 W**

Fuse ratings

The equation:

$$\text{current} = \frac{\text{electrical power}}{\text{voltage}}$$

is used to find the fuse rating of a device.

The correct fuse rating is that next above the normal current required by an appliance.

Example:

A 5A fuse should be used with a device that needs a current of 3.5A.

A 3-pin plug will normally contain a 3A, 5A or 13A fuse.

Question

Fuses of 3A, 5A and 13A are available.
What fuse should be used with a 60W, 230V lamp?

I* = *P* ÷ *V

= 60W ÷ 230V

= 0.26A

Fuse to be used = 3A

Answers

All of the devices below are 230V mains appliances.

Device and power (W)	***Normal current (A)***	***Fuse choice from: 3A, 5A or 13A***
Computer; 300W	**1.3 A**	**3A**
Microwave; 900W	**3.9 A**	**5A**
Charger; 10W	**0.04A**	**3A**
Heater; 2kW	**8.7A**	**13A**
2990W	**13A**	**13A**

Choose appropriate words to fill in the gaps below:

Electric power is the rate of conversion of electrical _energy_ to some other form and is measured in _watts_.

Electrical power is equal to electric current _multiplied_ by voltage. The greater the _power_ for the same voltage the _greater_ is the current drawn.

The correct fuse for a device is the next available value _above_ the normal current drawn by a device. The maximum fuse rating for a 3-pin plug is _13A_ for an appliance of power about _3kW_.

WORD SELECTION:

multiplied above 13A watts power greater 3kW energy

Electrical energy *E*

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

electrical energy (*E*) is measured in **joules (J)**

electric current (*I*) in **amperes (A)**

voltage (*V*) in **volts (V)**

time (*t*) in **seconds (s)**

Question 1

Calculate the energy used in joules by a 12V car starter motor when drawing a current of 80A for 3 seconds.

E* = *I* x *V* x *t

= 80A x 12V x 3s

electrical energy used = 2 880J

Question 2

Calculate the energy used in joules by a hairdryer of power 1kW in 1 hour.

$\boldsymbol{E = I \times V \times t}$

but electrical power $\boldsymbol{P = I \times V}$

and so: $\boldsymbol{E = P \times t}$

= 1 kW x 1 hour

= 1000 W x 3 600 seconds

electrical energy used = 3 600 000 joules (or 3.6 MJ)

Answers

P	*I*	*V*	*t*	*E*
1	10A	5V	4s	**2**
100W	**3**	50V	**4**	800J
5	3A	**6**	5s	450J
2kW	**7**	250V	3 min	**8**

Paying for electricity

An electricity meter is used to measure the usage of electrical energy.

The meter measures in **kilowatt-hours (kWh)**

A kilowatt-hour is the electrical energy used by a device of power one kilowatt in one hour.

Calculating cost

1 . Calculate kilowatt-hours used from:

kilowatt-hours = kilowatts x hours

2 . Calculate cost using:

cost in pence = kilowatt-hours x cost per kWh

Electricity currently costs about 12c per kWh

Question 1

Calculate the cost of using an electric heater of power 2kW for 5 hours if each kWh costs 12c.

kilowatt-hours = kilowatts x hours

= 2kW x 5 hours

= 10 kWh

cost in pence = kilowatt-hours x cost per kWh

= 10 kWh x 12c

= 120c

cost of using the heater = $1.20

Question 2

Calculate the cost of using a mobile phone charger power 10W for 6 hours if each kWh costs 12c.

kilowatt-hours = kilowatts x hours

= 10W x 6 hours

= 0.01 kW x 6 hours

= 0.06 kWh

cost in pence = kilowatt-hours x cost per kWh

= 0.06 kWh x 12c

cost of using the heater = 0.72c

Electricity bill

Calculate the cost of the electricity that you use over a three month period (90 days).

Typical power values:

energy efficient light bulb – 15 W

desk-top computer – 300 W

hairdryer – 2 kW

television – 100 W

charger – 10 W

Example: light bulb used for 4 hours per day:

kWh = (0.015 x 4 x 90) = 5.4 kWh; cost = 5.4 x 12c = 64.8c