Year 10 Double Award Science

Physics Revision Booklet

(exam date: Friday 14th June AM)

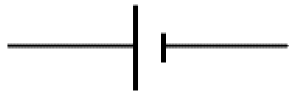
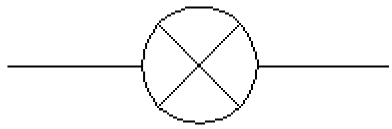
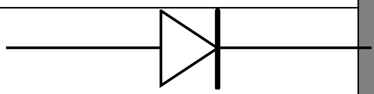
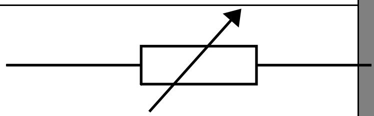
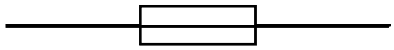
Name

Please use test results, feedback and self-assessment to colour code each section red, amber or green, and ensure that where you need to do extra work to improve, you use Prep time to do so.

	Understood	Revised
Unit 3.1 Electric Circuits		
Circuit Symbols		
Current and Voltage in Series Circuits		
Current and voltage in parallel circuits		
Using voltmeters and ammeters		
Current-voltage graphs for different components		
Ohm's law		
Resistance in series circuits		
Resistance in parallel circuits		
Power as energy transferred per unit time		
Electrical power as voltage x current		
Electrical power as current^2 x resistance		
Using light emitting diodes in circuits		
Using thermistors in circuits		
Unit 3.2 Generating Electricity		
Advantages and disadvantages of renewable technology		
Advantages and disadvantages of fossil fuels and nuclear technologies for generating electricity.		
How a fuel power station works		
Energy transfers and efficiency in %		
Using Sankey diagrams to show efficiency		
The National Grid and how it responds to demand		
Why we use different voltages at different parts of the National Grid, and the role of transformers.		
Power = Current x Voltage		
Comparing data about different types of power station.		
Unit 3.3 Making Use of Energy		
How temperature differences lead to the transfer of energy by convection, conduction and radiation		
Density		
Particle models of conduction and convection		
How to reduce energy loss from houses.		
The cost effectiveness and efficiency of house insulation		
Using data to investigate costs of heating and transport.		

Unit 3.4 Domestic Electricity		
The kWh		
Calculating cost of electricity		
Energy ratings and power ratings, and their cost.		
Alternating and Direct Current		
Fuses and circuit breakers		
The ring main circuit		
Microgeneration		
Payback time		
Unit 3.5 Features of Waves		
Transverse and Longitudinal Waves		
Amplitude, frequency, wavelength and wavespeed		
Labelling a transverse wave		
Drawing plane waves (e.g. water waves)		
Refraction		
The characteristics of the electromagnetic spectrum		
Uses of the electromagnetic spectrum		
Calculating wave speed		
Using Satellites		

Unit 1.1 - Circuits

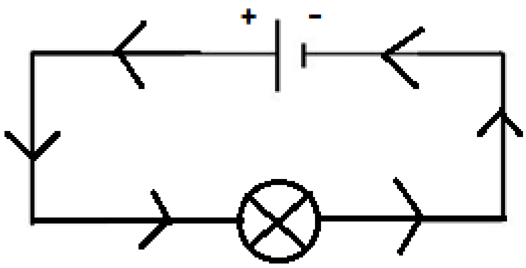
Device	Symbol	Device	Symbol
Wire		Cell / Battery	
Power Supply		Bulb	
Open switch (Off)		Closed switch (On)	
Diode		Resistor	
Variable resistor		Fuse	

Electrical current (I)

Current is the flow of free electrons (negatively charged). As a comparison, think of measuring the amount of water flowing through a pipe.

- Current is described as a measure of the charge that flows past a point every second.

  It flows from **+** to **–** .

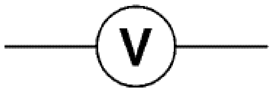


- Current is measured in **Amperes, A**.
- It is measured using an **Ammeter connected in series.**

Voltage (V)

Voltage is a measure of how much electrical energy a certain amount of electrons can transfer as they flow around a circuit. The higher the voltage, the more electrical energy is supplied to the circuit.

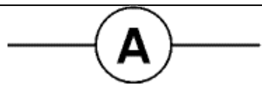
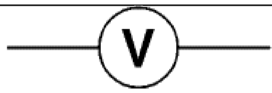
- Voltage is measured in **Volts, V**.
- It is measured using a **Voltmeter connected in parallel**.



Resistance (R)

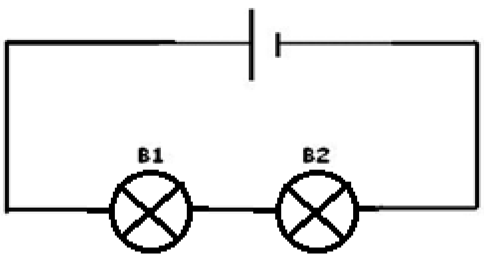
Resistance is a measure of how difficult it is for current to flow through a wire or device. More resistance means less current because it is more difficult for it to flow. Resistance is caused due to the collisions between the free electrons and the atoms/ions in the metal.

- Resistance is measured in **Ohms – Ω.**
- A thin wire has more resistance than a thick wire.

Name	Unit	Measured using	Symbol	Connected in…
Current	***Amps – A***	***Ammeter***		***Series***
Voltage	***Volts – V***	***Voltmeter***		***Parallel***
Resistance	***Ohms - Ω***			

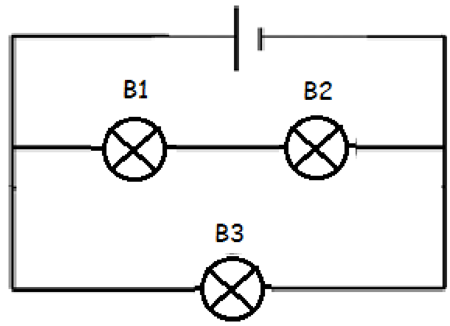
Series and Parallel circuits.

Series circuit: in a series circuit there is only path and the bulbs (B1 and B2) in the diagram below are one after the other. If bulb B1 breaks then B2 will not work/go off.



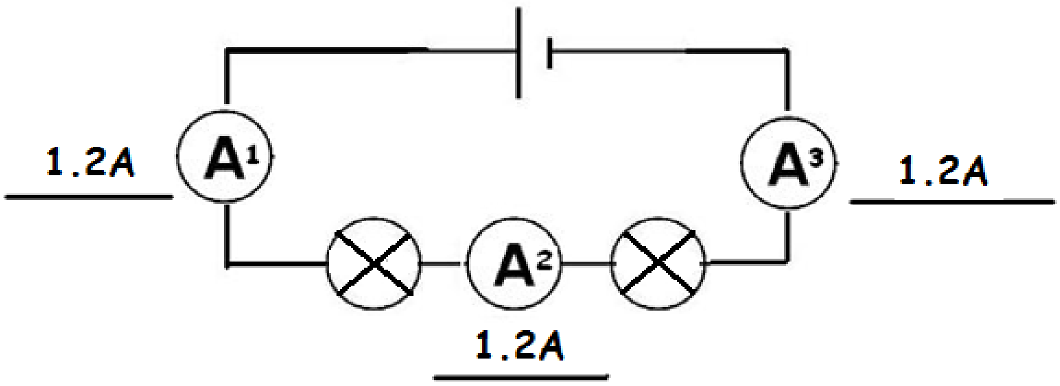
Parallel circuit: in a parallel circuit there is more than one path and the circuit is divided into branches. Bulbs B1 and B2 are in series but B3 is in parallel with them.

If bulb B3 breaks then B1 and B2 will continue to work.



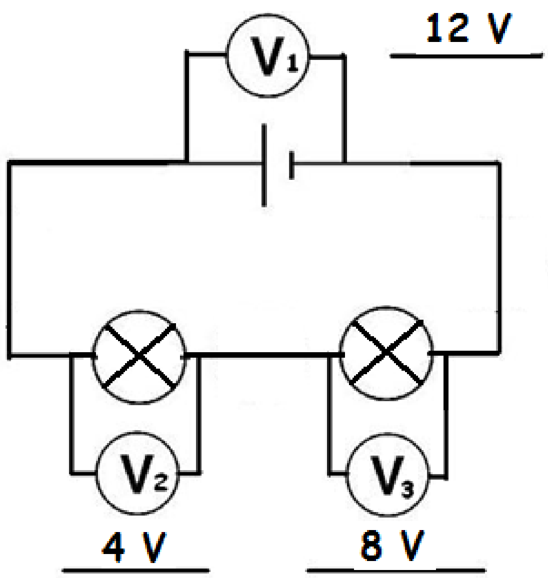
Measuring current and voltage in circuits.

Current in series circuits: ammeters must be connected in series i.e. in the circuit.



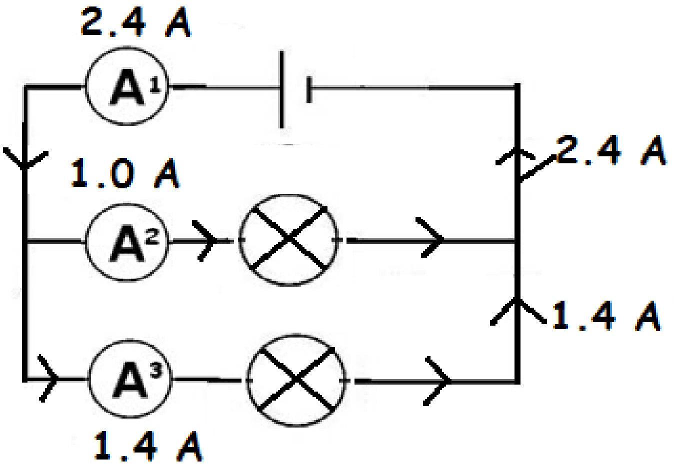
The value of the current is the same at all points ($A_1 = A_2 = A_3$) in the circuit since there is only one path for the current to flow.

Voltage in series circuit: the voltmeters are connected across the component e.g. bulb or battery.



The voltage across both components/bulbs here adds up to the voltage across the supply/battery i.e. ($V_1 = V_2 + V_3$) or (12 = 4 + 8).

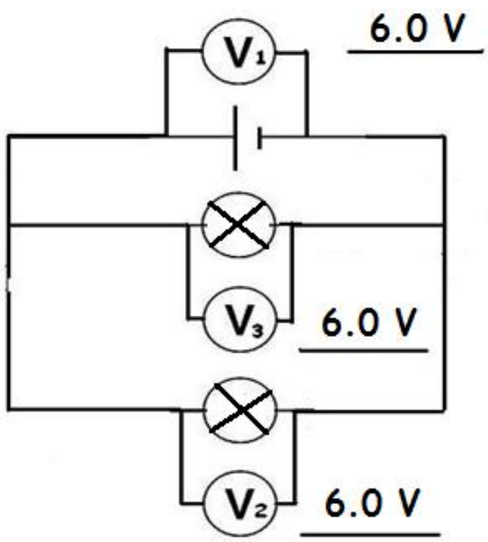
Current in parallel circuits: the ammeter in this series circuit is connected in series.



The value of the current in the two branches adds up to the total current flowing, i.e. ($A_1 = A_2 + A_3$) or (2.4 = 1.0 + 1.4).

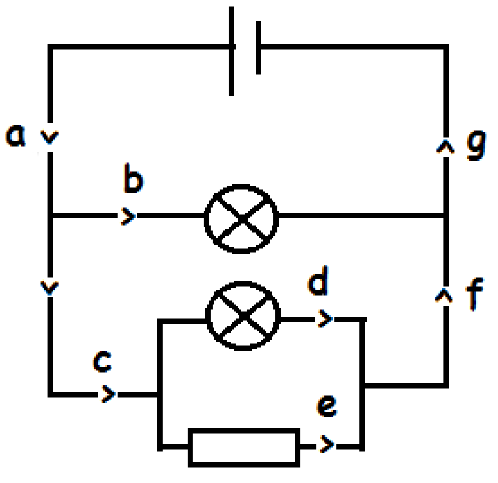
Voltage in parallel circuit: the voltage across all components in parallel is the same.

i.e. ($V_1 = V_2 = V_3$)



Predicting current values.

What is the value of the current at the following points in the circuit.



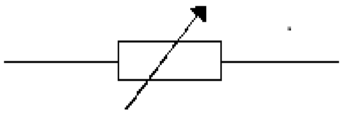
Point	Current (A)
a	3.6
b	2.0
c	
d	1.2
e	
f	
g	

Answers: c = 1.6A, e = 0.4 A, f = 1.6A, g = 3.6A

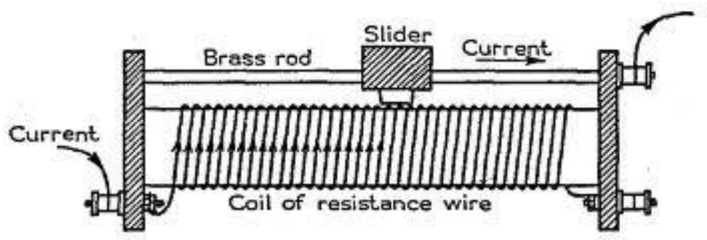
Variable resistors (controlling the current).

In your house the mains voltage is 230V. Not all devices require the same current to operate and some will have two or three settings (like a toaster or hairdryer) so we must have a way of changing/controlling the current required.

A variable resistor (rheostat) is a resistor for which it is possible to alter/vary the resistance. Variable resistors are components that can be put into a circuit to control the current and the voltage e.g. volume control and dimmer switch



If you look at the variable resistor below then the more the slider is over to the right hand side the more wire the current has to go through so the greater the resistance and therefore the current decreases.

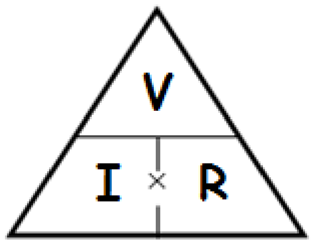


Wire-wound rheostat

Ohm's law

This law describes the relationship between voltage (V), current (I) and resistance (R).

Resistance = $\frac{\text{Voltage}}{\text{Current}}$



Higher tier only

$$R = \frac{V}{I} \quad \text{or} \quad V = I \times R \quad \text{or} \quad I = \frac{V}{R}$$

e.g. Calculate the voltage across a 15Ω resistor that carries a current of 1.8A.

V = 1.8 x 15 = 27 V

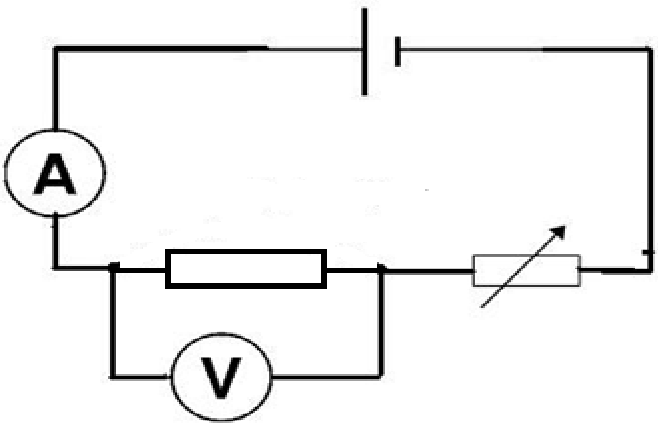
Q1. Calculate the current through a 2kΩ resistor when there is a voltage of 230V across it.

Q2 An electric fire with 4A flowing through it has a voltage of 230V across. Calculate the resistance of the wire in the electric fire.

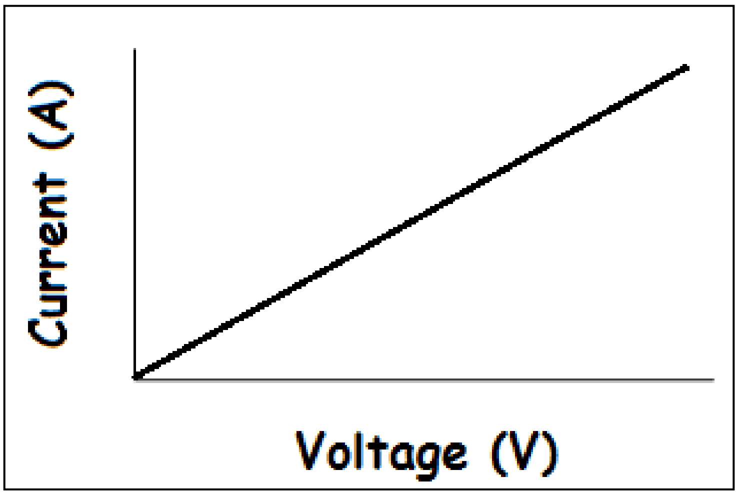
Answers: Q1 = 0.115 A , Q2 = 57.5 Ω

Current – voltage relationship

Resistor or wire at constant temperature. Moving the variable resistor changes the resistance of the circuit so that you can then change and measure the voltage across the resistor/wire and the current flowing through it.



A graph of the voltage and current are plotted. Key features of the graph are:



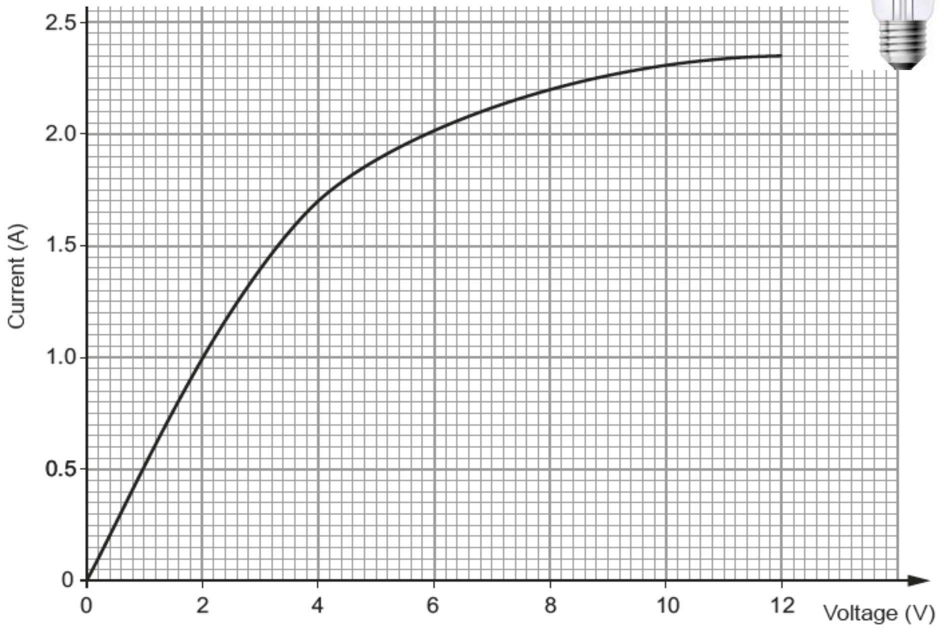
- The graph shows that if the voltage across the wire/resistor is doubled then the current also doubles.
- The relationship between the current and voltage is **directly proportional**. The relationship is only directly proportional if the graph goes through the origin (0,0) and is a straight line.
- This only happens if the **temperature of the wire remains constant.**
- The constant gradient of the graph means that the ***resistance remains constant*** and that the resistor/wire ***obeys Ohm's law.***

Changing resistance

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}} \quad \text{or} \quad R = \frac{V}{I}$$

If the voltage remains constant then if the resistance of ***resistor/wire doubles*** then the ***current will halve***. This relationship is ***inversely proportional.***

Filament lamp (NOT constant temperature). The same circuit as for the resistor/wire is used, except the resistor is changed for a bulb.



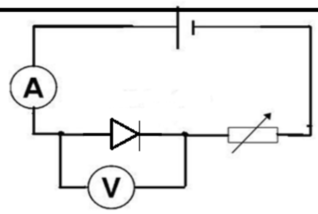
- Up to 2V the current and voltage increase at the same rate because the resistance is constant (constant gradient).
- From 2V to 12V the current increases at a slower rate than the voltage.
  The gradient is not constant so the **resistance is not constant**.

The ***resistance of the lamp increases*** because the temperature of the filament wire is increasing. Therefore the filament lamp does **NOT** obey Ohm's law.

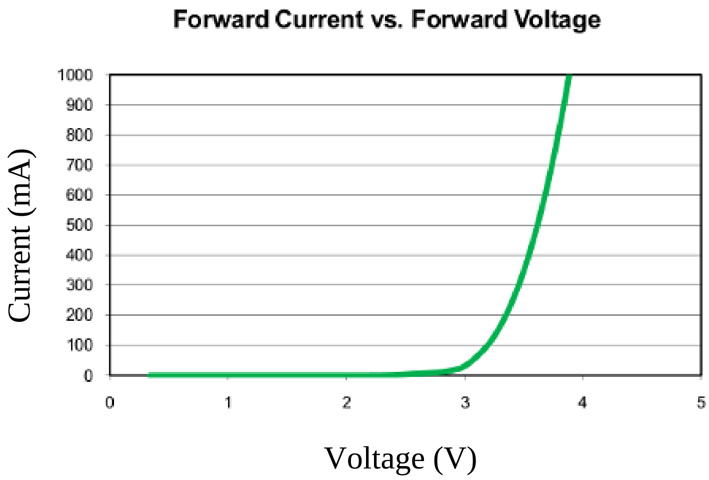
Calculate the resistance of the lamp at (i) 2 V (ii) 12 V.

$R = \frac{V}{I}$ (i) $R = \frac{2.0}{1.0} = 2.00\ \Omega$ (ii) $R = \frac{12.0}{2.35} = 5.11\ \Omega$

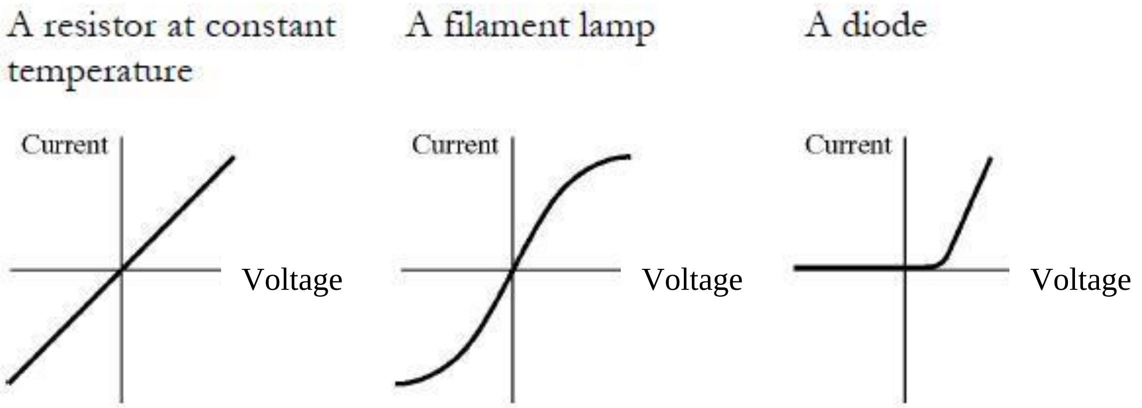
Diode (usually a Light emitting diode, LED). The same circuit is used again, except the resistor is changed for a diode ➔.



- Up to a certain voltage (2.8V in this case), there's no current at all – any devices connected in series with the LED would be off.
- Above this minimum voltage, the LED starts conducting, and the current increases rapidly (the resistance of the LED is reducing).
- If the LED were connected the opposite way (reversed) then it wouldn't conduct at all – the graph would remain horizontal.



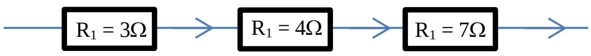
Summary – Current-Voltage graphs



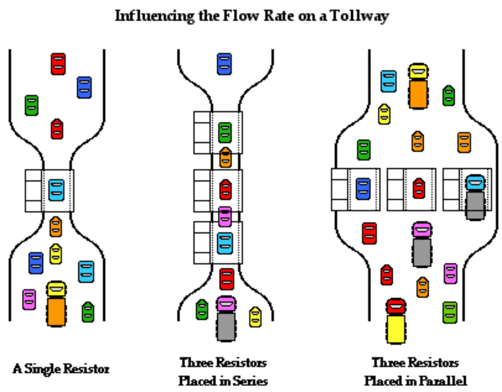
Resistor combinations

Resistors in series

The more resistors that are added in **series**, the greater the resistance. In fact, the total resistance is simply the sum of all the resistors, e.g. $R_T = R_1 + R_2 + R_3 = 3+4+7 = 14\Omega$.



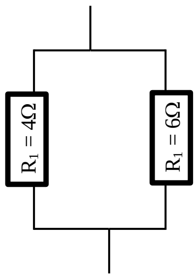
<u>HIGHER TIER ONLY</u>



Resistors in parallel

When resistors are added in **parallel**, the total resistance decreases. If you compare the flow of electricity to the flow of cars through a toll ➔ you can see that more tolls placed in parallel means the cars flow more easily. Likewise, when more resistors are added in parallel, there are more channels for the current to flow through, and hence there's less resistance.

Example : To calculate the total resistance of these ➔ 2 resistors, we use the following equation,



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{6} = \frac{5}{12}$$

$\therefore \quad R_T = 12 / 5 = 2.4\ \Omega$

Use a calculator for these !

Example 2. A 100Ω, 400Ω are connected in parallel with another resistor of 250Ω which is connected in series, Calculate the total resistance.

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{500} \qquad \frac{1}{R} = 0.0125 \qquad \frac{R}{1} = \frac{1}{0.0125} \qquad \therefore\ \mathbf{R = 80\Omega}$$

Total = 80 + 250 = 330 Ω

Electrical Power.

This is the **rate** (per second) of energy transfer i.e. the amount of energy a device can transfer from one form to another per second. (Hence, P = E / t). Power is measured in WATTs, W.   In electrical circuits, we can also use the equation,

Power = Voltage x current,   P = V x I

Device	**Power (W)**	**Energy transferred every second. (J/s)**	**Energy transferred into heat every second. (J/s)**	**Energy transferred into light every second. (J/s)**
Filament bulb	60.0	60.0	56.0	4.0
LED bulb	6.0	6.0	0.4	5.6

HIGHER TIER ONLY - Power, current and resistance.

If we want to calculate the power consumption of an electrical component in a circuit but we do not know the voltage then we can do so by combining two equations.

Power = Voltage x Current   ***substitute***   **Voltage = current x resistance**

P = V x I   V = I x R

$P = V \times I \longrightarrow P = (IR) \times I \longrightarrow P = I^2 \times R$

Power = current^2 x resistance

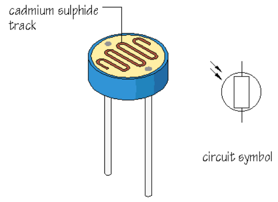
Example: A 2kΩ resistor has a current of 0.80A flowing through it. Calculate the power of the resistor. First we must change 2kΩ into Ω by multiplying by 1000.

Resistance in Ω = 2 x 1000 = 2000 Ω   then,

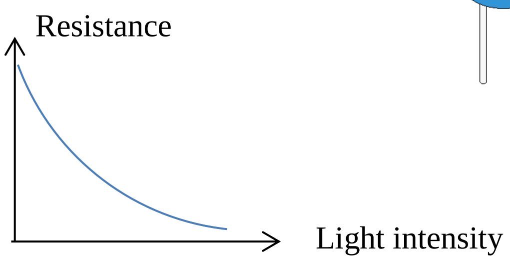
Power = current^2 x resistance = 0.8^2 x 2000 = **1280 W**

LDRs and Thermistors.

Light dependent resistor, or **LDR**

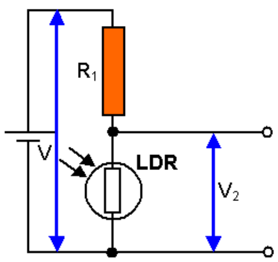


The LDR is a component that has a resistance that changes when light falls on it. As the intensity of the light is increased so the resistance of the LDR falls.



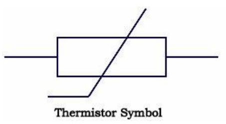
If the LDR is connected as part of a circuit as shown in the diagram then as the light level is increased its resistance falls and the proportion of the input voltage across it will also fall.

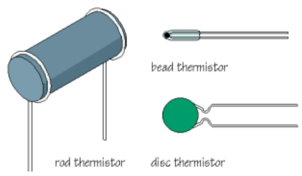
So in the light V_2 is LOW and in the dark V_2 is HIGH.
This type of system is used to automatically switch on street lights, as one example.



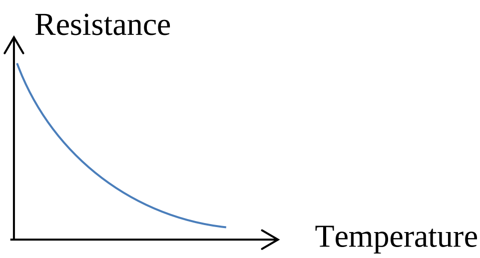
Thermistors (ntc)

A temperature-sensitive resistor is called a **thermistor**. There are several different types:





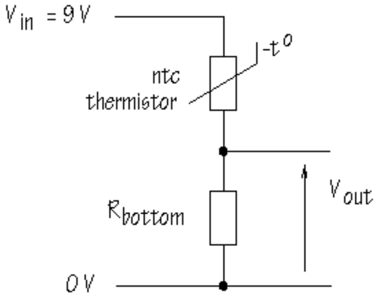
The resistance of most common types of thermistors **decreases** as the temperature **increases** :



Example of the use of a thermistor

How could you make a sensor circuit for use in a fire alarm? You want a circuit which will deliver a HIGH voltage when hot conditions are detected.

So, as the temperature increases, the thermistor's resistance decreases. This means less of the input voltage is now across the thermistor, and more across the resistor (R_{bottom}) – raising the alarm !

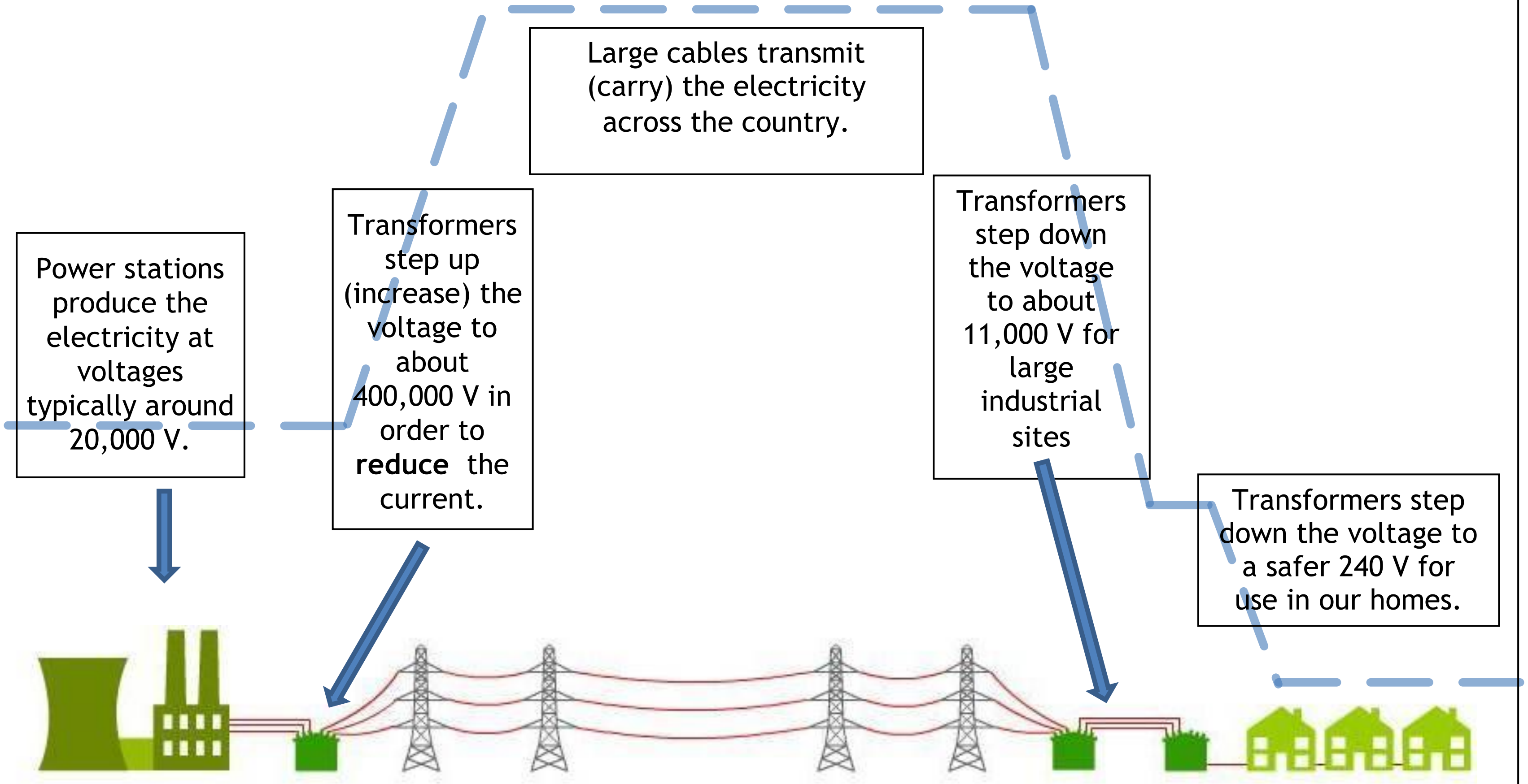


Unit 1.2 - The National Grid (Producing electricity)

The National Grid is the system of power stations, cables (& pylons), and transformers that supply electrical energy to our homes, schools, industries etc.

The main benefit of getting our electrical energy from a “grid” like this is that it is very reliable.

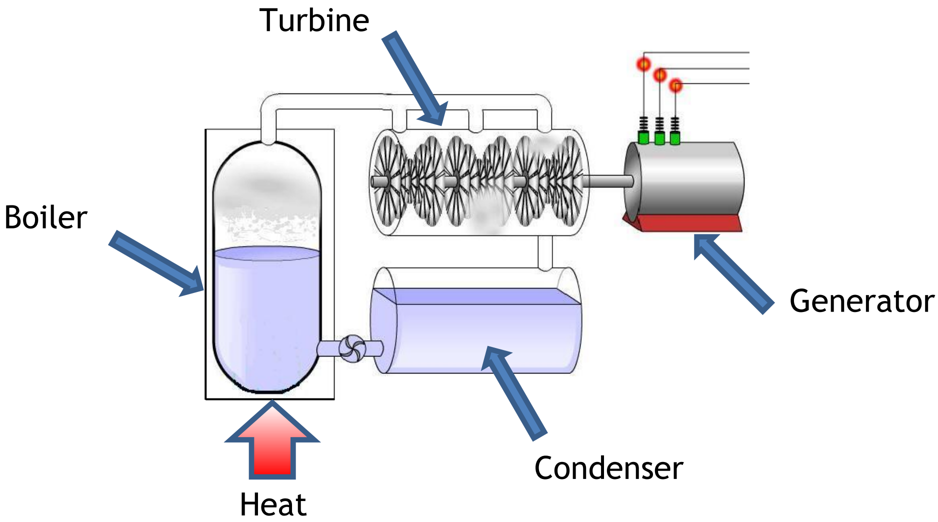
The only other option to produce electricity is **micro-generation** (e.g. solar panels on the roof; small wind turbines in the garden, etc.)



Producing electrical energy

There are 3 main ways to produce electricity for use in the national grid.

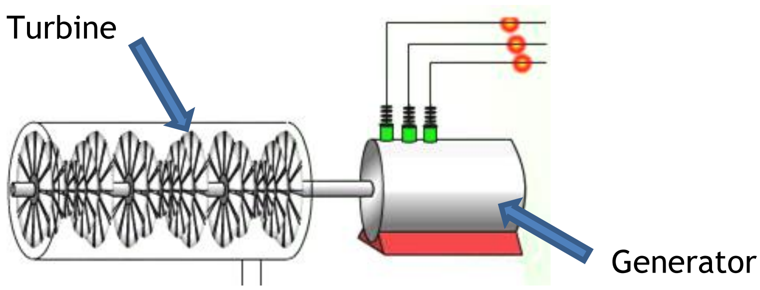
1. Shown below is a typical set-up for most power stations. The fuel is used to provide heat energy to water in a boiler. The water changes to steam which turns the blades of a turbine. The turbine is connected to a generator which then produces electricity.



Coal, oil & gas power stations work like this by burning the fuel.

Note that a nuclear power station also works as shown in the diagram, but that nuclear fuel doesn't "burn" in the usual way, and so doesn't release CO_2.

2. Shown below is a typical set-up for most other types of 'generators', e.g. hydroelectric ; tidal ; wave ; wind.
Water or air strikes the blades of a turbine to make it turn.
The turbine is connected to a generator which then produces electricity.



3. **PV (photovoltaic) solar cells convert light energy directly to electrical energy.**

Comparing the different power stations

All power stations need an energy **resource**, i.e. a source of energy that can be converted to electrical energy. All these resources are classed as either **renewable** or **non-renewable**.

A renewable resource is a resource we can make more of it in a short amount of time e.g. biomass, or is produced continually e.g. wind or rain (hydroelectricity).

Renewable	Non-renewable
Geothermal	Coal
Solar	Oil
Wind	Gas
Waves	Nuclear
Tidal	
Hydroelectric	
Biomass	

These are fossil fuels. When they are burned to produce heat, they also produce Carbon Dioxide (CO_2). CO_2 is a greenhouse gas that causes global warming.

Costs

One wind turbine

Wylfa Nuclear power station

At first glance it may look like wind power is a much cheaper option, however, to make a fair comparison, we must quote these **commissioning** (build) cost values **per MW (M**ega **W**att) of electricity produced :

Wind farm : Each wind turbine costs £80 000, and produces about 25,000 Watts.
Number of wind turbine needed to make 1 MW = 1,000,000 W ÷ 25,000 W = 40
Total cost = 40 x £80,000 = £3.2 million **per MW**

Nuclear : Total commissioning cost is £2,000 million (£2 billion). Total electrical power produced is about 650 MW.
Therefore, Cost per MW = £2,000 ÷ 650 = £3.1 million **per MW**

So, in fact, the build costs are almost identical ! However, it's not quite this simple . . .
Other costs to consider are : Day-to-day **Running costs, Decommissioning costs** (the safe dismantling of the power station when it becomes too old).

Comparing the different power stations

In the Physics exam., you may be given data, usually in a table, and you will have to compare different power generation systems. Although you are not expected to know all the details for all the different power stations etc., it may be wise to know some basic advantages and disadvantages.

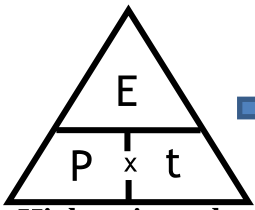
Type	Advantages	Disadvantages
Nuclear	No CO_2, reliable, generate large amounts of electricity and uses small amount of fuel.	Radioactive waste produced which needs to be stored for a long time, high commissioning and decommissioning costs and risks with terrorism.
Coal, Oil and Gas	Generate large amounts of electricity. Can be built in many locations.	CO_2 (global warming) and SO_2 (acid rain for coal) produced, transport of fuel is difficult and getting a secure supply.
Hydroelectric	No CO_2, generate large amounts of electricity, no fuel costs and start up time is short.	Need to flood large area of land, destroy wildlife habitats and building of large dams.
Wind	No fuel, no air pollution.	Eye-sore, unreliable, generate small amount of electricity.
Solar	Cheap to install on buildings, fairly reliable, no air pollution.	Need a lot of panels to generate large amount of electricity and does not work at night.
Geothermal	No air pollution, reliable	Ground source heating needs large area.
Biomass	Can generate large amount of electricity and carbon neutral.	Large areas of land needed to grow trees and plants.
Wave and tidal.	Tidal predictable. No air pollution. Tidal could generate large amounts of electricity	Wave more unreliable as it depends on the wind. Tidal could cause loss of wildlife areas.

Note : *A big debate at the moment is that the decommissioning cost (demolition etc.) for a nuclear power station is much more than originally estimated. Much of this is because the radioactive sections of the reactors stay dangerously radioactive for decades. Some estimates put the decommissioning cost at around £50 billion ! When this is accounted for in the overall costs of a nuclear power station, the price of the electricity is higher than it seems at present.*

Power equations

In general, power refers to how much energy is transferred per second. So, the equation for power is : Power = Energy ÷ time

$$P = \frac{E}{t}$$



Higher tier only

...and the other two forms of the equation are :

$$E = P \times t$$

$$t = \frac{E}{P}$$

Energy is measured in **Joules (J)**
Time is measured in **seconds (s)**
Power is measure in **Joules per seconds (J/s)** or **Watts (W)**

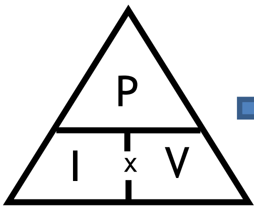
> ***Example***
>
> If the power of a kettle is 3000 W, and it's on for 3 minutes, how many Joules of energy has it converted ?
>
> Answer : E = P x t = 3000 x (3x60) = 540 000 J

Look !!! The time must be in **<u>seconds</u>**, not minutes.

In electrical circuits, there's also another equation for power :

Power = current x voltage

$$P = I \times V$$



Higher tier only

...and the other two forms of the equation are :

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

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

Current is measured in **Amps (A)** Voltage is measured in **Volts (V)**

> ***Example***
>
> If the power of a hair dryer is 1.2 kW, and it's working on "mains" power (voltage = 240 V) what's the current flowing ?
>
> Answer : I = P / V = 1200 / 240 = 5 Amps (or 5 A)

Transmitting electricity

There are 2 major problems with getting electricity from the power stations to our homes, schools, industries etc :

1. Heat energy is wasted in the cables

2. Electricity can't be stored on a large scale

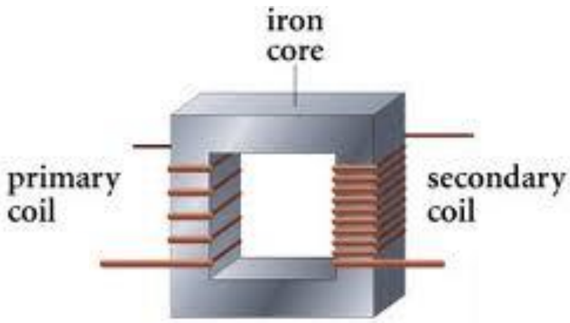
Info. ! *How much electricity flows in a wire is known as electrical* ***current.***

1. Heat energy is wasted in the cables

Typically, power stations produce electricity with a total current of about 10,000 Amps.
This is a **very** large current, and will cause a lot of heat to be produced in all the wires/cables carrying the electricity around the country !

If nothing were done, there simply wouldn't be enough electrical energy left to work all our devices in our homes.

It's the flow of electricity through wires, i.e. the **current**, that produces heat. So, if we want to reduce the heat produced in wires, we need to keep the current to a minimum. This is how it's done :



A step-up transformer !

Higher voltage → Lower current → Less heat wasted in the wires

So, if the input voltage was, say, 20,000 Volts, and the step-up transformer increased this by a factor of 20 (20,000 x 20 = 400,000 V), then the current would reduce by a factor of 20.

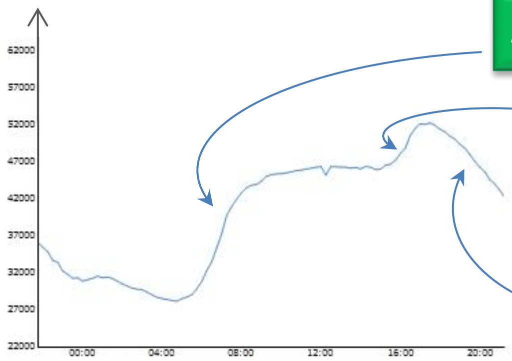
Note : The transformer creates no extra electrical power, so the input power is the same as the output power. The equation " Power = current x voltage " (P=IxV) can be used to calculate the effect on the current, when the voltage is changed.

Transmitting electricity

2. Electricity can't be stored on a large scale

Since it is **not** practical to store electrical energy on a large scale, the right amount of it must be produced every second of every day. This causes a big headache for the national grid, as it has to try to get the right balance between **supply** (how much is produced) and the **demand** (how much is needed).

Energy supply in MW (Mega Watts).



A surge in the morning when people wake up.

A surge in the evening at meal time.

A drop when people are going to bed.

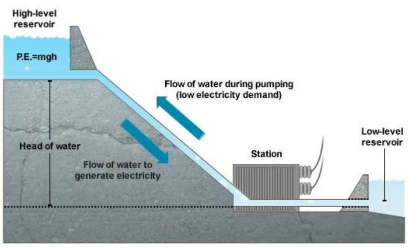
Note that "one-off" special events can cause surges too, as well as day-to-day events, e.g. a popular event at the Olympics; the FA cup final etc. The National Grid try to predict when these occur by looking at the TV listings !

A surge in demand can cause a black-out (no electricity across a large part of the country) unless the National Grid respond very quickly. More electricity is produced within seconds by fast-response power stations like "Electric mountain" in Llanberis, N.Wales – a hydroelectric power station.

When needed they open a few valves, which allow water in the upper lake to flow down through turbines.

Power stations in order of increasing start-up times.

Shortest	----------------------------->		Longest
Hydroelectric	Gas	Coal	Nuclear



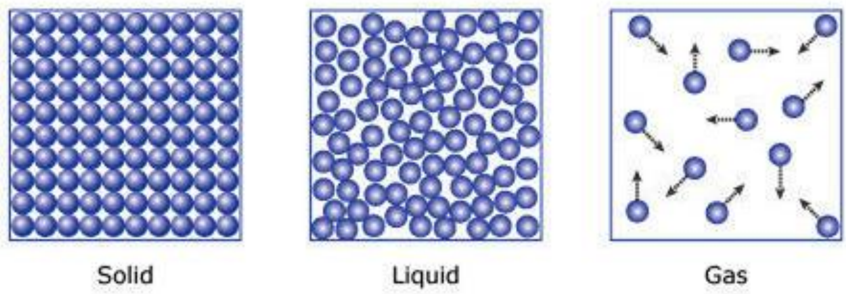
A fast-response hydroelectric power station (pump-storage). Electricity can be imported from other European countries in times of high demand.

Unit 1.3 - Making use of Energy

Density

Density tells us how much mass of a certain material is contained within a certain volume.
The more material in a given volume, the greater the density.

So, in general, solids have high density values whereas gases have very low values:

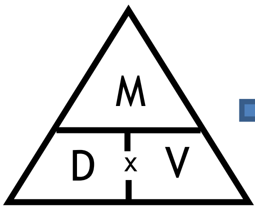


Here's the equation for calculating density :

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

...and the other two forms of the equation are :

$$D = \frac{M}{V}$$



Higher tier only

$$V = \frac{M}{D}$$

$$M = D \times V$$

Example

Calcuate the density of a glass block, length = 14cm, width = 4.5cm, height = 2cm, whose mass = 315g.

Volume of the block = $l \times w \times h$ = *14 x 4.5 x 2* = ***126 cm³.***

So, density of block, D $= \frac{M}{V} = \frac{315}{126} =$ **2.5 g/cm³**

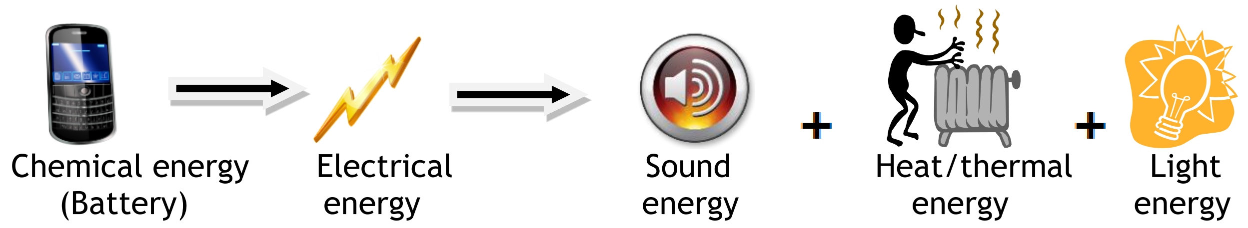
Water has a density of exactly 1 g/cm³ (or 1000 kg/m³).
Air has a density of about 0.0013 g/cm³.

This is why a turbine driven by a certain volume of water is capable of generating more electricity than a turbine driven by the same volume of air. 1 m³ of water weighs about 854 times the same amount of air.

Energy Transfer

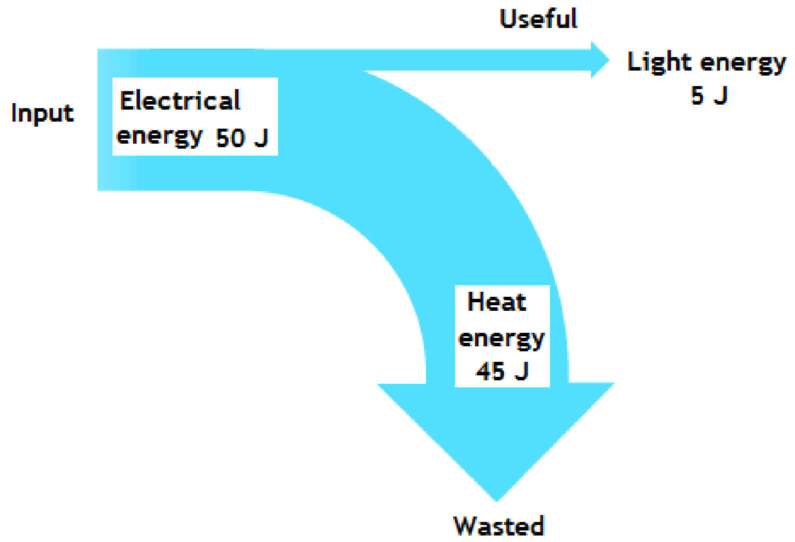
Type of energy	Example
Electrical	Into hairdryer.
Heat	Cooker.
Kinetic	Moving energy - car.
Sound energy	Speaker
Light energy	An object which emits light - LCD screen.
Chemical energy	Stored in food/battery.
Gravitational potential energy	Increases with height above ground - pump storage station.
Elastic potential energy	Stored in stretched elastic band/spring.

Example: energy transfer



Sankey Diagrams

Energy transfers can be shown using **Sankey** diagrams. They show the energy types which are involved and also the amount of energy involved. Below is a Sankey diagram for a filament bulb.



Key points

- Energy input = Energy output: 50 J (input) = 45J + 5 J (output)
- Useful energy is straight on.
- Wasted energy is curved downwards/upwards.
- Width of arrow tells us the amount of energy (to scale)
- Width of arrow is proportional to the amount of energy. They are drawn to scale e.g. 10J = 5mm

Efficiency

Energy efficiency: this is a measure of how much useful energy comes out of a device. It is measured in %.

$$\% \text{ Efficiency} = \frac{\text{USEFUL energy out (or power) tranfer}}{\text{TOTAL energy (or power) input}} \times 100$$

Example: using the data from the Sankey diagram.

$$\% \text{ Efficiency} = \frac{5}{50} \times 100 = 10\%$$

This is very poor and shows that the bulb is not very efficient. You cannot get more than 100%!!!

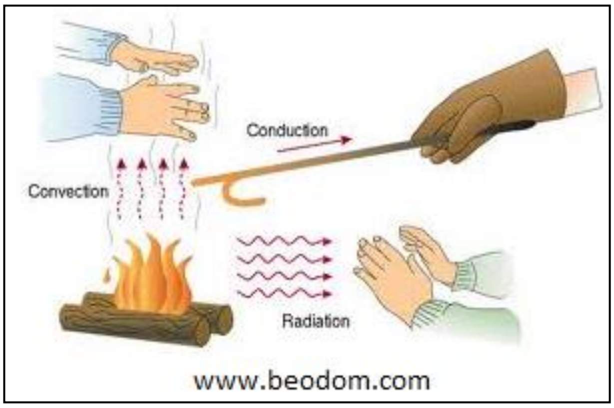
Coal power station 35% efficient, LED lights are 90% efficient and car engine 40% efficient.

The more efficient a power station is the ***less energy*** that is needed to be burnt so the ***less carbon dioxide*** emitted and also fossil fuels last longer.

Thermal energy (heat) transfer.

Thermal energy moves from **HOT** (High temperature) to **COLD** (lower temperature) (down a temperature gradient) e.g. a hot cup of tea gives out thermal energy to the surroundings.

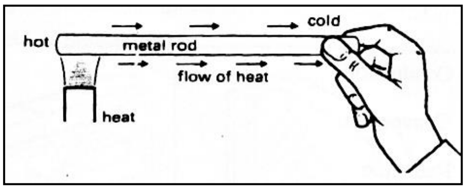
The greater the ***difference in temperature*** the more thermal energy transferred per second e.g. so the temperature of your mug of tea will drop at a greater rate when it is very hot.



3 types of thermal transfer: Thermal energy can be transferred via conduction, convection and radiation.

Conduction: In conduction the thermal energy flows through the object itself. It takes place in solids and liquids.

Conductors: materials which are good at conducting thermal energy e.g. metals like copper. The main reason metals are such good conductors of heat is because they have **free electrons.**



Insulators: materials which are poor at conducting e.g. air, plastic. Many materials which are insulators like wool trap air e.g. jumper.

Convection: Heat flows by convection in **liquids** and **gases** only. Convection cannot occur in solids because the particles are fixed.

This applies to liquids and gases:

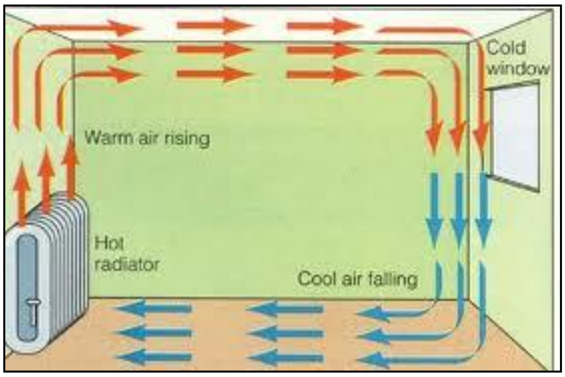
1. When gas/liquid heated.

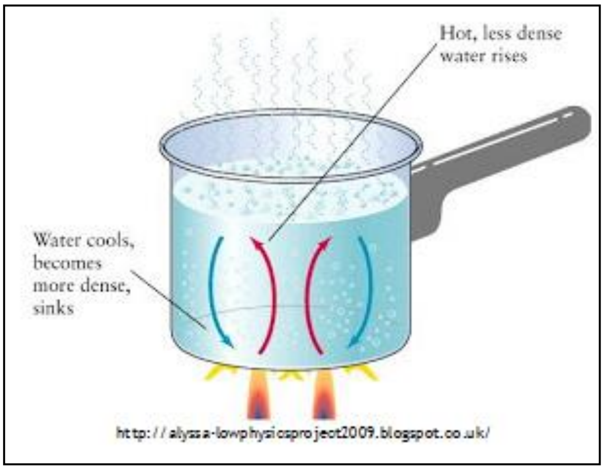
2. The particles speed up

3. Volume of gas/liquid increases. Gas/liquid expands.

4. Density decreases and so gas/liquid rises.

5. Colder, denser gas/liquid falls.





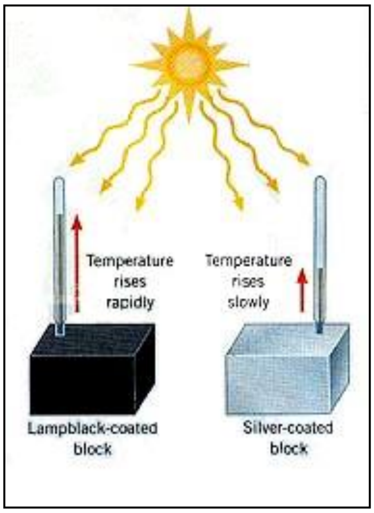
Some materials like foam trap air, which reduces the convection current. This reduces heat loss/transfer through convection.

Thermal Radiation (infrared). Any hot object will emit thermal radiation in the form of infrared electromagnetic radiation.

The higher the temperature of an object the more thermal radiation it will emit. This is the only means of heat transfer through a vacuum (space). Objects can ***emit*** and ***absorb*** heat radiation

Shiny objects are good at reflecting thermal radiation e.g. aluminium foil around food, caravans painted white.

Matt black objects are very good at absorbing/emitting thermal radiation e.g. wood burning stove is painted black and black cars become hotter in the sun.



Dull Black | **Shiny Black** | **Colours (dark --> Light)** | **White** | **Silver**

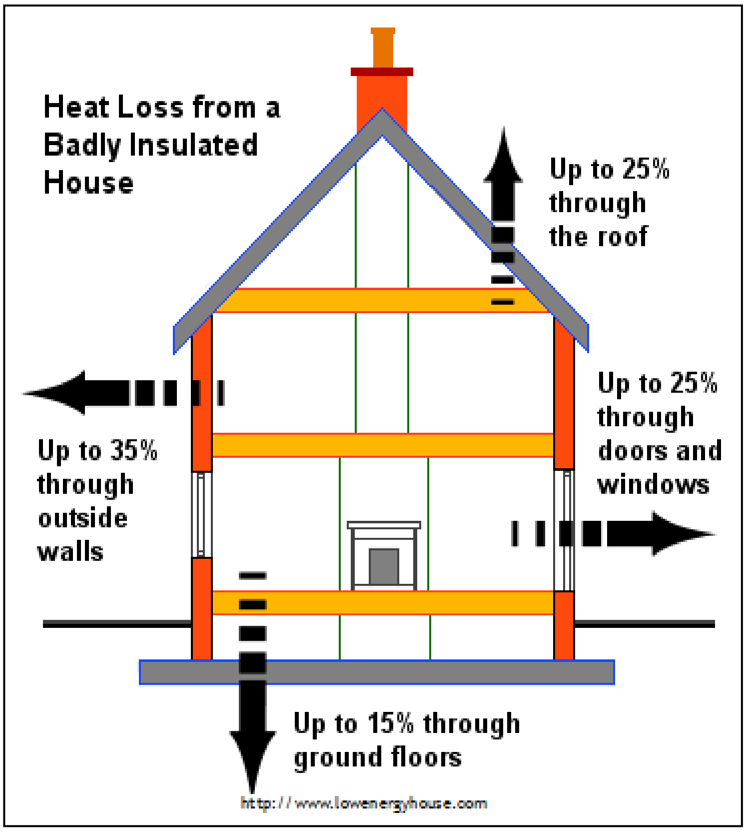
Best Emitter/ Absorber

Poorest Emitter/ Absorber

Insulating the house

It is important to try and reduce the thermal energy loss from a house. This will reduce ***energy bills*** (saving money) and also reduce the ***carbon dioxide emissions*** as the result of heating your home. CO_2 is a greenhouse gas which increases global warming.

There are many types/systems of insulation that can be installed in the house to reduce **NOT stop** heat loss. Most of these insulating materials work because they ***trap air*** which is a poor conductor. If the air is trapped heat loss through convection is reduced because warm air cannot rise and cold air cannot fall.



Insulating systems

Insulation type/system	How it works.
Double glazing	Two sheets of glass separated by a gap filled with e.g. argon or a partial vacuum. It reduces heat loss through conduction and convection.
Draught proofing	Strips of draught proofing can be fitted around doors and window frames. Draught excluders can be placed at the bottom of doors. It reduces heat loss through convection.
Loft insulation	Rock wool (mineral wool) can be placed between the rafters in the loft. These materials are good at trapping air. Reduces the heat loss through conduction and convection.
Floor insulation	Fibreboard or mineral wool is placed to reduce heat loss via conduction and convection.
Cavity walls	Walls are built with an inner and outer wall. The gap/cavity can be filled with foam or insulation board which reduces conduction and convection.

Installing wind turbines and solar planes DO NOT reduce heat loss

Note: The higher the temperature of the inside of your house compared to the outside the more energy your house will lose per second because of a greater difference in temperature.

Comparing the costs

There are 2 main energy requirements in the home :

1. Electricity

2. Heat

You will be expected to compare the different energy sources in terms of their cost, their effect on the environment, **payback time**, etc.

"Payback time" is the time it takes to get the money back in energy savings for the money spent on a particular improvement. Here's the equation for calculating "payback time" :

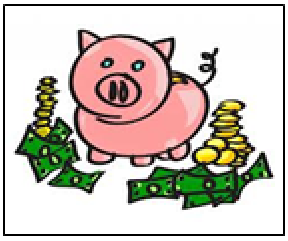
$$\text{Payback time (in years)} = \frac{\text{installation cost}}{\text{annual savings}}$$

Note : This equation is not given in the exam at all, so you'll have to memorise it !!

So, payback time can be calculated by dividing the cost of the system with the saving per year (how much your bill has been reduced).

Example: it costs £4000 to install double glazing in your house. Your energy bills are reduced by £175 per year. How long will it take before the cost of your investment is paid back.

$$\text{Payback time} = \frac{4000}{175} = 22.9 \text{ years.}$$



You will <u>not</u> be expected to remember data about different energy sources, only use what is given in the exam question.

See the example on the next page.

Comparing the costs

Example from a past paper

1. A householder is considering using a **renewable** energy source to help him save money on electricity bills. He used some information from a local store to draw up the following table.

	Installation cost (£)	Saving per year (£)	Payback time (years)	Maximum power output (W)	Conditions needed
Wind turbine	1200	600	2	5400	Average wind speed 4 m/s, (maximum 12 m/s)
Roof top photovoltaic cells (PV) of area 4 m^2	14000	....	7	1800	South-facing roof

(a) What is meant by a renewable energy source ? [1]

(b) (i) Complete the table by calculating the saving per year for the roof top Photovoltaic cells (PV). [1]

(ii) Give reasons why the payback times for the wind turbine and roof top photovoltaic cells (PV) may be different from both those shown in the table.[3]

(iii) Calculate the area of roof top photovoltaic cells (PV) needed to produce the same maximum power as a wind turbine.[2]

(c) Explain how the introduction of roof top photovoltaic cells (PV) and wind turbines would benefit the environment. [2]

Answers

(a) Easily replaced / replenished / will not run out / sustainable

(b) (i) [£] 2000

(ii) Wind - variable wind speed (1) Solar - hours of sunshine / roof may not face South or intensity of Sun (1) Fuel costs could change (1)

(iii) 5400 ÷ 1800 = 3 (1 mark)

3 x 4 = 12 m^2 (1 mark)

(c) Reduces CO_2 (1) which reduces the greenhouse effect / global warming (1) or
Less SO_2 (1) which results in less acid rain (1) or
Use less fossil fuels (1) so less extraction needed / less CO_2 / less SO_2 (1)
("less pollution" not accepted as it's not specific enough).

Comparing the cost of different energy sources used in transport

Scenario : You and 2 friends are planning a trip to see your favourite group in concert in Paris ! (One of the parents is driving you there and back !). Each of the 3 families have the same car, but each car uses a different fuel.

Distance from Llanrwst to Paris (one way) = 750km

Fuel type	Cost per litre (£ / l)	Fuel used to travel 100km (l / 100km)
Diesel	1.15	5.46
Petrol	1.13	6.31
Liquid Petroleum Gas (LPG)	0.65	7.41

Use the data below to calculate the fuel costs to drive from Llanrwst to Paris **and back,** for each fuel type.

Step 1 : Calculate the total distance travelled for the journey there **and back.**

Total distance = 750km x 2 = 1500 km

Step 2 : Use the 3rd column to calculate the total amount of fuel used by each type of car.

Diesel

Fuel used = 1500 ÷ 100 = 15
= 15 x 5.46
= 81.9 L

Petrol

Fuel used = 15 x 6. 31
= 94.65 L

LPG

Fuel used = 15 x 7.41
= 111.15 L

Step 3 : Use the 2nd column to calculate the cost of those amounts of fuel.

Cost = amount of fuel x cost per litre
= 81.9 x 1.15 = £ 94.19

Fuel	Amount of fuel (l)	Cost (£)
Diesel	81.9	94.19
Petrol	94.8	107.12
LPG	111.2	72.24

Unit 1.4 - Domestic electricity

Calculating the cost of electricity

When electricity companies need to calculate your electricity bill, they simply count how many "units" (kWh) of electrical energy you've used since your last bill. The Joule is much too small for the electricity companies.

1 kWh is the electrical energy converted by a 1 kW (1000W) appliance used for 1 hour.

The two equations needed to calculate the cost of electricity are:

Units used (kWh) = power (kW) × time (h)

cost = units used × cost per unit

The number of units of electrical energy used are therefore measured in "kilo-Watt-hours"

Once the "number of units" (kWh) has been calculated, it is then easy to calculate the cost of the electricity - see the example below :

Example

If the power of a microwave oven is 850 Watts, and is on for a total of 30 minutes, calculate the cost of the electricity it uses if each unit (kWh) costs 12 pence.

÷ 1000: W → **kW**

÷ 60: minutes → **hours**

Units used = P (kW) x t (h) = 0.85 x 0.5 = 0.425 kWh

Cost = 0.425 x 12 pence = 5.1 pence

Converting between kWh and Joules

The 1st step is to change the kilo (k):

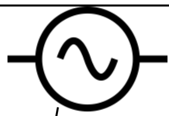
5 kWh x 1000 → 5000 Wh

The 2nd step is to change the hours to minutes and then seconds:

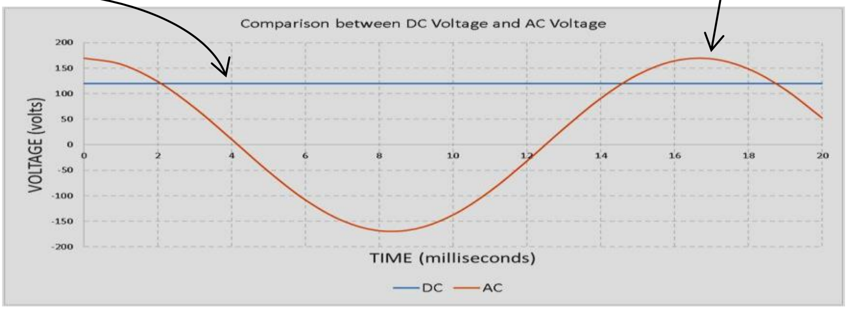
5000 Wh x 60 x 60 = 18,000,000 J

AC/DC

An **alternating current (a.c.)** is one that continuously changes direction.
e.g. Mains electricity is an a.c. supply. The UK mains supply is about 230V and has a frequency of 50Hz.



A **direct current (d.c.)** has a constant direction.
e.g. Cells and batteries.



Electrical Safety

Two wires supply our homes with electricity. One is called

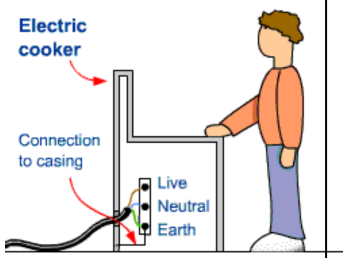
1. **LIVE** (brown), carries the current to the house/appliance at a high voltage. Switches and fuses are placed into the live wire.

2. **NEUTRAL** (blue), completes the circuit and carries the current away at low/zero voltage.

There is one more wire in the home:

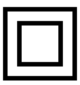
3. **EARTH**: (yellow and green) – is a safety wire which can carry current safely into the ground if a fault develops in a metal framed appliance.

The Earth Wire

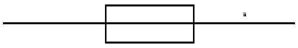


If the electrical device has a metal case there is a danger that a person may receive an electric shock if the live wire touches the metal case. This can kill you. To prevent this from happening, the metal case is connected to the earth wire in the plug, which means that the current would go straight the low-resistance earth wire. The strong current would blow the fuse or trip the mcb (miniature circuit breaker) and break the supply/circuit.

Double Insulation



Some appliances have the above symbol. Not only are the wires insulated with a plastic sheath (as usual), but the device has another layer of electrical insulation, e.g. it may have an outer casing that is entirely made of plastic, and so does not need an Earth wire.

The Fuse: 

The wire in the fuse is very thin. If too large a current flows due to a fault in the device, the wire inside the fuse becomes hot and melts or 'fuses'.
This prevents the device from overheating or catching fire.
The fuse will not protect you from an electric shock if you touch the live wire.

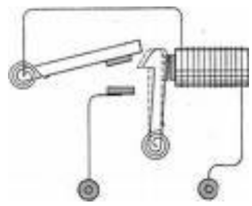
3 common fuses are available: 3A, 5A, and 13A.

Disadvantages of the fuse:

1. A fuse works relatively slowly and therefore you could receive a bad shock before the circuit breaks.
2. It is possible to receive a shock with a current that is too low to break the fuse.
3. A new fuse needs to be inserted every time it blows.

Miniature Circuit Breaker - mcb

There is an electromagnet inside the circuit breaker. When the current becomes large enough the strength of the electromagnet is enough to separate the connections and break the circuit.



- A circuit breaker can be used instead of a fuse.
- It works very quickly (a hundredth of a second).
- A circuit breaker can be reset.

Disadvantage: Exactly like the fuse, it does not protect from electric shocks with a low current. So, you could still receive a shock if you touch the live wire.

Residual Current Circuit Breakers (rccb)

This device is placed in a socket first, and then the equipment is plugged into the device. Its purpose is to protect the user from electric shocks.

Live wire current = neutral wire current → everything working correctly.

If someone accidentally touched the live wire, some of the current would flow through their body to the earth. Then,

Live wire current > neutral wire current → Circuit breaks

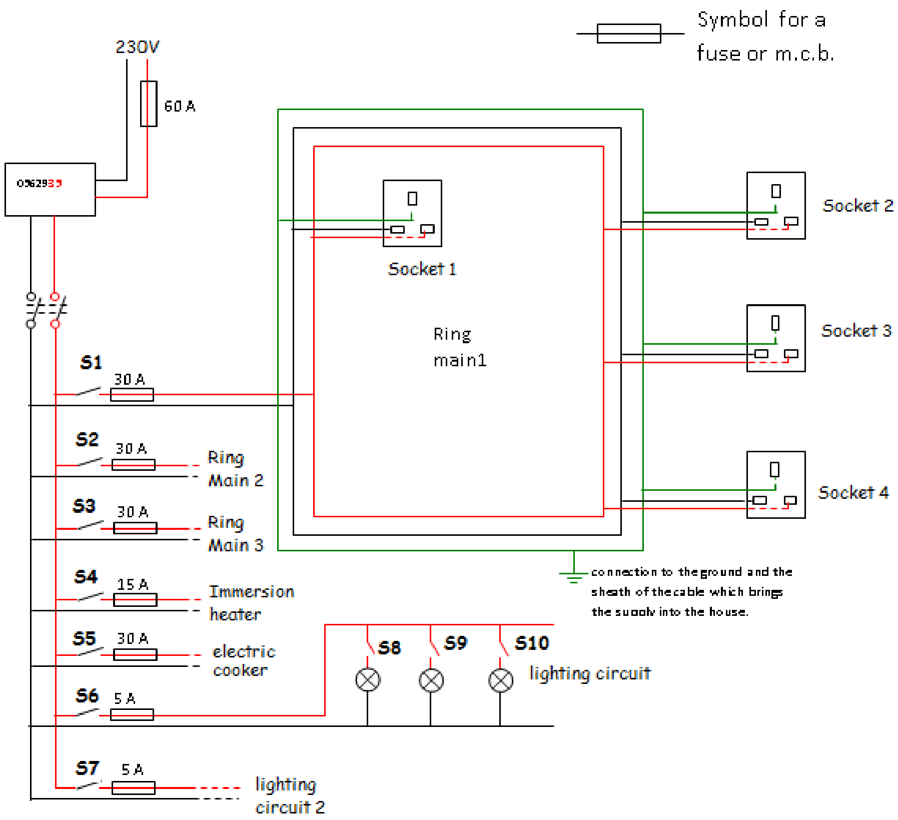
Main Advantages:

- ***Protects the user whereas the mcb protects the appliance***
- Works very quickly (0.001seconds).
- Very sensitive and works with a very small difference in the current (0.003A).
- Can be reset.

Ring Main.

Advantage of a ring main

1. The cables can be made thinner because there are two paths for the current.
2. Each part of the cable carries less current because the current flows both ways.
3. A ring main circuit is more convenient since sockets can be placed anywhere on the ring.
4. Each socket has 230V and they can be operated separately.



1. What is the voltage across socket 1? Answer= 230 V

2. Which switch would you use if you wanted to do maintenance work on ring main1? S1

3. What is the maximum power that could be supplied to the electric cooker?

P = V x I

= 230 x 30

= 6900 W

4. There are 3 identical bulbs in the lighting circuit, and they each require a current of 0.05A. Calculate the total power of the 3 bulbs.

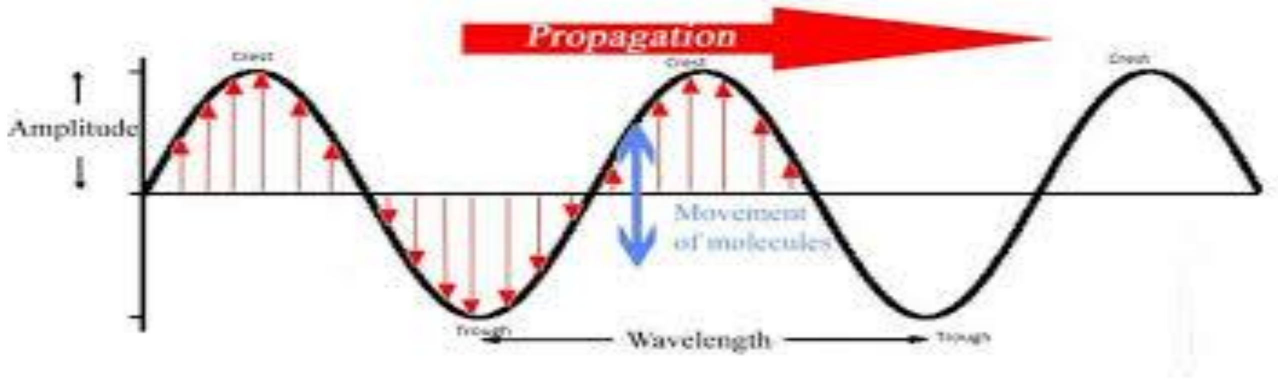
Total current for all bulbs = 0.05 + 0.05 + 0.05 = 0.15 A

Power = voltage x current = 230 x 0.15 = 34.5 W

Unit 1.5 - Waves

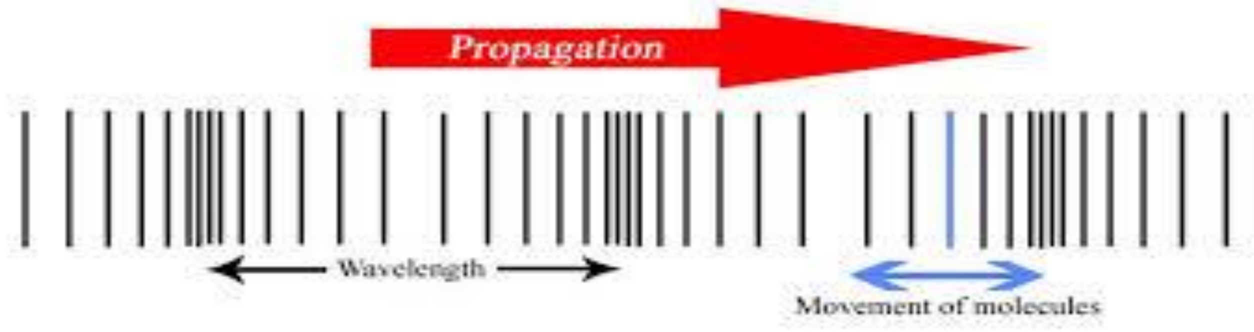
Basic information

Transverse: ***The oscillations of the particles are at right angles (90°) to the direction of travel (propagation) of the wave.***



Examples: All electromagnetic waves (Light, microwaves etc), S-waves,

Longitudinal waves: ***The oscillations of the particles are in the same direction as the wave is moving.***



Examples: Sound waves, P-waves

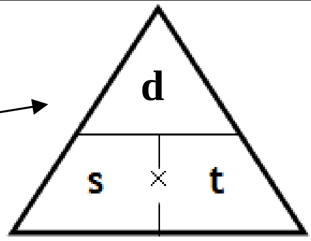
Characteristics	What is it?	Units
1.Wavelength λ	The distance from a crest to the next crest or the distance it takes to repeat itself.If there are 10 waves in 5 metres then the wavelength is 0.5m	Metres, m
2. Frequency **f**	The number waves per second. 1 Hz is 1waves per second. If there are 40 waves in 10 seconds then the frequency is 4 Hz.	Hertz, Hz
3. Amplitude	Distance from the middle of the wave to the crest/top. The greater the amplitude the more energy the wave is carrying.	Metres, m

Calculations involving waves.

The speed of a wave can be calculated in 2 ways.

1. Speed = distance / time

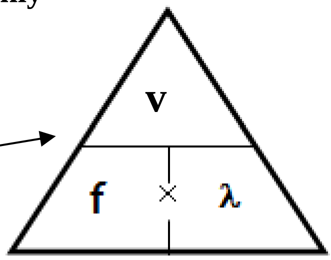
$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$



Higher tier only

2. wave speed = frequency x wavelength

$$c = f\lambda$$



Higher tier only

<u>Example 1:</u> A gun is fired and person 1200m away hears the shot 4 seconds after the gun is fired, what is the speed of the sound wave? Since distance and time is given we must use the first equation (always show your working).

$$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{1200}{4} = 300 \text{ m/s}$$

<u>Example 2</u>: A water wave moves at a **speed** of 2.5 m/s. Its **wavelength** is 7.5 m. Use the correct equation from to calculate the **frequency** of the wave. We use the 2^{nd} equation since speed and wavelength are given.

Speed = frequency x wavelength

Rearrange the equation, $\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{2.5}{7.5} = 0.33 \text{ Hz}$

<u>Example 3</u>: Light from the sun travel a 150,000,000 km at a speed of 300,000,000 m/s (3×10^8 m/s). Calculate the time in minutes it takes for the light to reach us here on Earth.

We have to units to change here: 150,000,000 km, into metres

150,000,000 km x 1000 = 150,000,000,000 m or 1.5×10^{11} m

$\text{speed} = \frac{\text{distance}}{\text{time}}$, rearrange

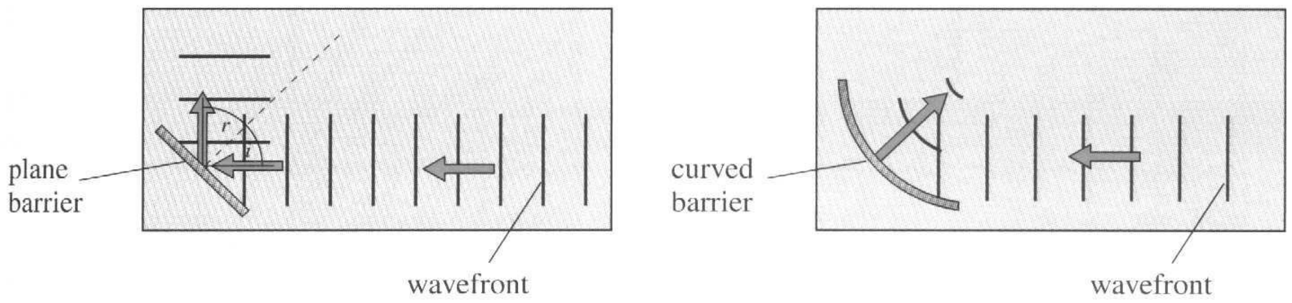
$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{150{,}000{,}000{,}000}{300{,}000{,}000} = \frac{1.5 \times 10^{11}}{3 \times 10^{8}} = 500 \text{ s}$$

Changing seconds into minutes: $\frac{500}{60} = 8.3$ minutes

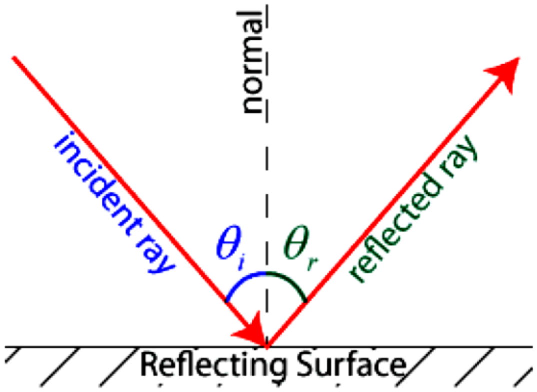
Properties of waves

Reflection. As the waves strike a plane (flat) barrier they are reflected. This is very similar for a beam of light reflecting on a plane mirror. If a curved (concave) barrier such as a satellite dish is used, the waves can be made to converge (concentrate) at a point. The angle of incidence and reflection will be equal.

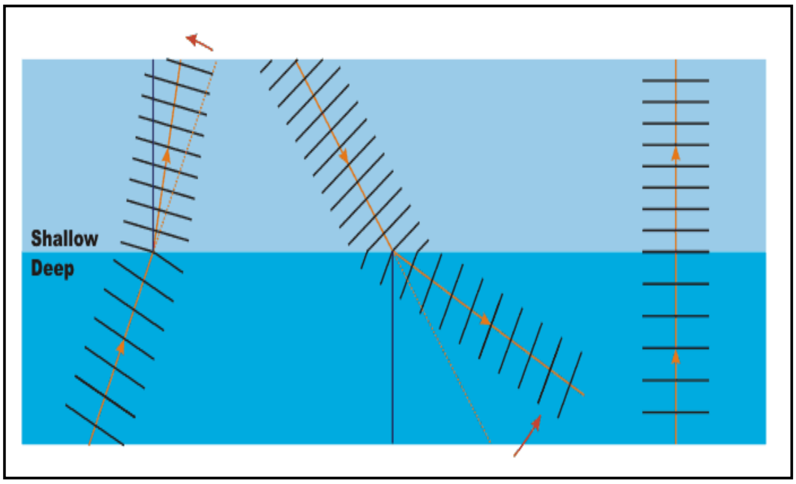
Reflection on a satellite dish.



The angle of incidence and reflection will be equal.

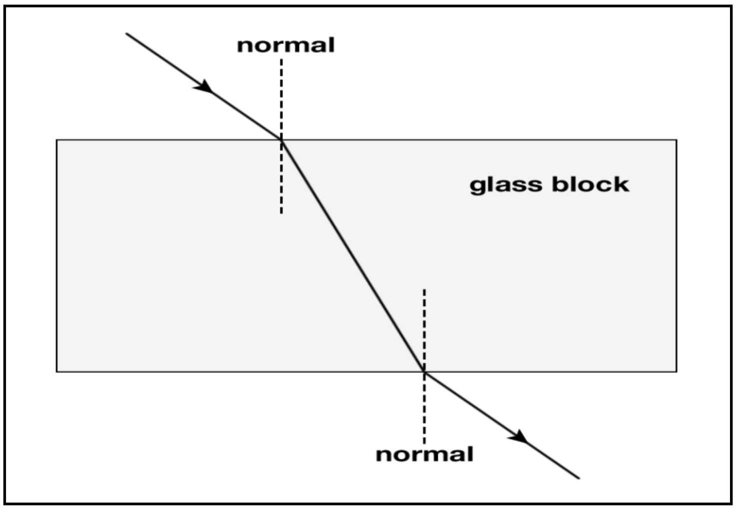


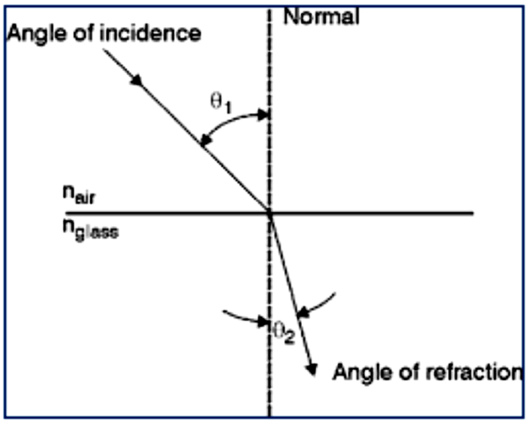
Refraction: Refraction is the change in direction of a wave at the boundary between two materials. This is caused by a change in speed.



Water. This occurs when water waves pass between deep and shallow water. The waves move more slowly in shallow water. The ***frequency of the waves remain constant*** and so the wavelength decreases. When the waves move from shallow to deeper water, their speed increase and they change direction away from the normal

Refraction of Light. When light passes in between materials of different optical densities, it causes the light ray to refract. When the light moves from air to glass it slows down, and bends towards the normal. When the light emerges from the glass block it speeds up and bends away from the normal (opposite direction).

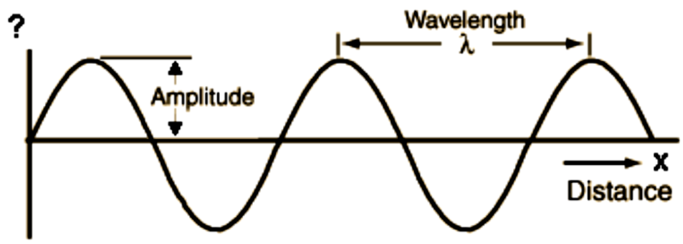




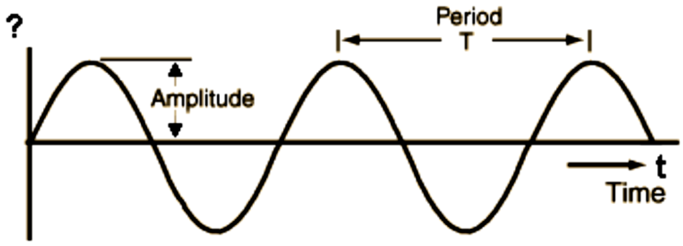
Changes in wavelength are proportional to changes in wave speed. This is true since the frequency remains constant.

Displacement-time and displacement-distance graphs

This graph is a snapshot of the whole wave at an instant in time.

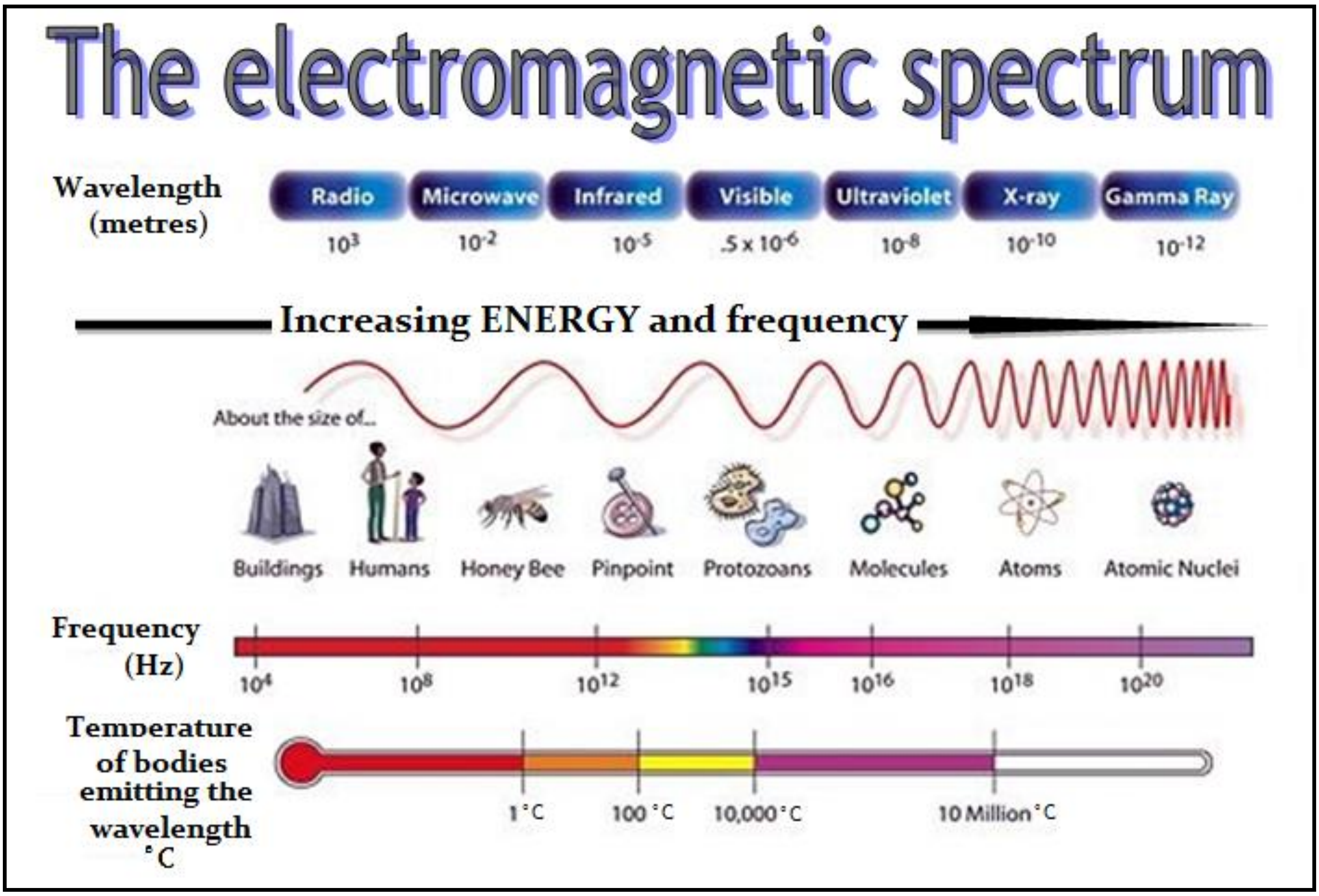


This graph shows the motion/ movement of one particle in the wave over time.



The electromagnetic spectrum.

A family of waves that have similar properties.



The frequency and energy increase from radio to gamma.

The wavelength decreases from radio to gamma.

Note: they do not have to arrange the spectrum in this order, they could do it starting with gamma on the left (it would still have the most energy).

Common properties of the electromagnetic spectrum:

1. **Travels at the same speed in a vacuum. (300,000,000 m/s or $3x10^8$ m/s)**
2. **Transfers energy/information from one place to another.**
3. **They are transverse waves.**

Uses of the em spectrum.

Part of em spectrum	Properties/dangers.	Uses
Radio	Longest wavelength, no known dangers.	Radio and television signals.
Microwave	Short wavelength. Some concern that they pose a health risk to phone users. Absorbed by water molecules.	Heating food, satellite and mobile phone communication.
Infrared (thermal radiation)	Longer wavelength than visible light. Can burn if you get too much exposure.	Transmitting information in optical fibres, remote controls and infrared cameras
Visible light	If the light is too bright it can damage the eye/retina.	Photosynthesis. Lasers in CD players.
Ultraviolet	Can ionise cells in the body leading to skin cancer.	Sun tan beds, detecting forged bank notes.
X-rays	They are ionising which can lead to cancer.	Medical imaging, inspection of metal fatigue and airport security.
Gamma	The most ionising in the em spectrum because they have the most energy.	Cancer treatment - killing cancer cells and sterilising medical equipment or food.
Ionising radiation is to interact with atoms and to damage cells by the energy they carry.		

Radiation emitted by objects. (Higher tier only)

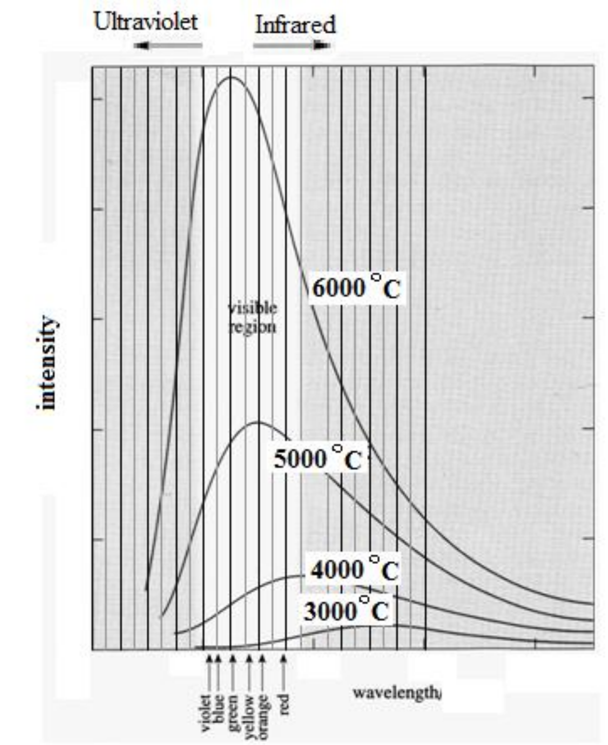
Hot objects emit radiation over a ***wide range of*** wavelengths.

- The **higher the temperature** of an object, the greater the **amount of radiation emitted.** The frequency also increases, and the shorter the wavelength of the peak emission/highest intensity.

- At room temperature objects emit weakly in the infra red.

- An incandescent (giving out light) light bulb (at about 2700°C) filament emits much more strongly – in the visible and infra red.

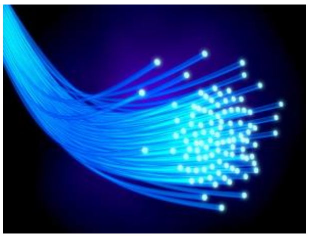
The Sun (at about 5500°C) radiates very strongly/mainly in the visible but also in the infra red and ultra violet.



Comparing forms of communication.

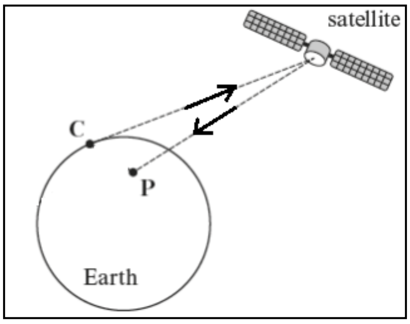
Optical Fibres. The signal is sent using **infrared** light because it can travel further within the cable than visible light. These cables are laid between the continents. The signals travel at 200,000,000 (2×10^8) m/s and can carry more information (1.5 million phone calls per cable).

The advantages of optical fibre over traditional copper cables are



1. They require fewer boosters to increase strength of the signal.
2. More difficult to bug (tap into) the signal.
3. They weigh less.
4. Use less energy.
5. No interference from neighbouring cables.

Satellites.

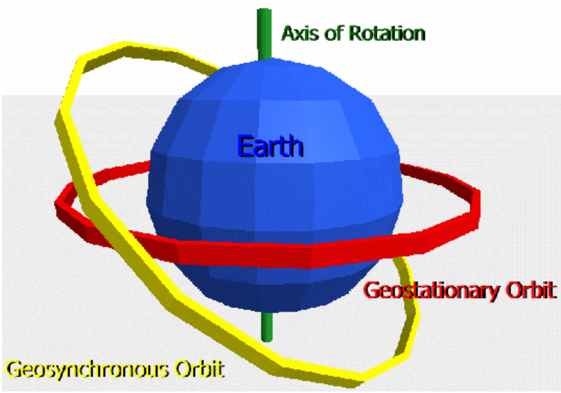


Communication satellites need to be in a **geostationary orbit** (36,000 km high) because Satellite needs to be above a fixed point on the Earth so satellite dishes (e.g. sky dish) do not have to be moved.
They use **microwave** radiation to send signals to the satellite because it can pass through the atmosphere.

To send a signal from C to P, the signal must travel from C to the satellite and relayed back to P. To send a signal a greater distance then more than 1 satellite can be used.

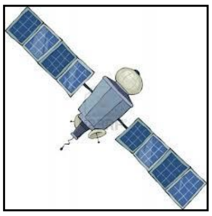
Definition of* geosynchronous *orbit: *has an orbit time of 24 h however the object in this orbit only returns to exactly the same position in the sky after a period of one day.*

Definition of* geostationary *orbit: the satellite is remains above the same point on the Earth's surface (above equator) and takes 24 hours to complete an orbit (which is the same as the Earth's period of rotation).



The distinction being that while an object in geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position. A base station can be in constant communication with a geostationary satellite but only once every 24 h with a geosynchronous satellite.

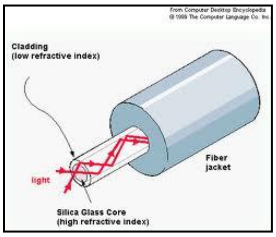
Time delay.



Method 1, satellite: If the distance from the Earth's surface to each satellite is 3.6×10^7 m, the total distance the microwaves must travel to go from Wales to Italy is (up and down once) = $\mathbf{2} \times 3.6 \times 10^7 = \mathbf{7.2 \times 10^7}$ **m**

Microwaves are electromagnetic waves so travel at 3×10^8 m/s.

$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{7.2 \times 10^7}{3 \times 10^8} = \mathbf{0.24\ s}$$



Method 2, optical fibres: The distance from Wales to Italy is about 2000 km =

2×10^6 m.

Infrared waves travel at about **70%** of the speed of light in an optical fibre, so, $0.7 \times 3 \times 10^8 = \mathbf{2.1 \times 10^8}$ **m**

$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{2 \times 10^6}{2.1 \times 10^8} = \mathbf{0.0095\ s}$$

There is less time delay with optical fibres and they are not affected by the weather.