

GCSE Physics

21st Century Science

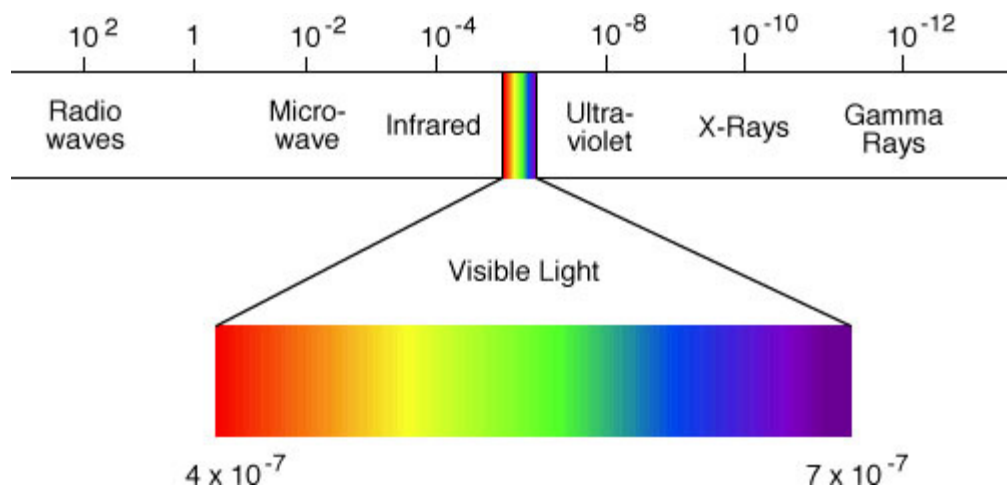
P2: Radiation and life

Name: _____

The electromagnetic spectrum

A combination of electric and magnetic energy is known as electromagnetic energy. It exists in packets called photons. These photons vibrate up and down as they travel. The distance between two peaks [or troughs] of a wave trace is called a wavelength [m]. One complete vibration [or cycle] consists of one complete peak and one complete trough. The number of cycles / second is known as the frequency of the wave trace.

Different electromagnetic photons have different frequencies and wavelengths. The greater the frequency [and therefore the shorter the wavelength of an electromagnetic wave, the more energy it has. Ultraviolet light has a high frequency and is very energetic. It can cause skin cancer and can kill.



Question: What is the wavelength of the following:

[a] Red visible light _____

[b] Microwaves _____

[c] Gamma rays _____

Question: Which electromagnetic wave has the highest frequency? _____

Refraction from a prism

The pattern produced when white light shines through a prism is called the visible **spectrum**.

The prism separates the mixture of colours in white light into the different colours red, orange, yellow, green, indigo and violet.

In fact, visible light is only part of the **electromagnetic spectrum**. It's the part we can see.

Some types of electromagnetic radiation are used to transmit information such as computer data, telephone calls and TV signals.

Ultraviolet light in sunlight has both its advantages and disadvantages

Advantage: It is absorbed by skin cells and is used to make vitamin D. Vitamin D is a nutrient, which strengthens bones, teeth and muscles. It boosts the immune system, which protects you from infections. It can also prevent the growth and spread of cancers in the breast, colon, ovary and other organs.

Disadvantage

Ultraviolet light is so energetic that it can ionise atoms in DNA [remove their electrons and leave them with an electric charge]. The DNA cannot replicate properly and so the cell becomes cancerous and can turn into a tumour. Over a lifetime, the risk of developing a type of skin cancer called malignant melanoma is 1 in 91 [UK males] and 1 in 77 [UK females]. Electromagnetic radiation comes in tiny 'packets' called **photons**. The photons deliver different quantities of energy, with radio photons delivering the smallest amount, and gamma photons delivering the greatest amount of energy.

A higher frequency of electromagnetic radiation means more energy is transferred by each photon. If the photons have enough energy, they can break molecules into bits called ions. This is called ionisation. These types of radiation are called **ionising radiation**. This radiation can remove electrons from atoms in its path.

In the *electromagnetic spectrum* only the three types of radiation, which have the photons with most energy, are ionising. These are **ultraviolet, X-rays** and **gamma rays**.

Prevention of skin cancer

The skin naturally produces a brown pigment called melanin on exposure to sun light [suntan]. We can help melanin by applying a high factor sunscreen.

Question: Dark, highly melanin pigmented skin can block a lot of ultraviolet light from getting into skin cells. What is the disadvantage of this? What foods should be recommended to these people?

Correlation or cause?

A study of 2600 people found that people who were exposed to high levels of sunlight were up to four times more likely to develop a cataract [clouding of the eyes]. Exposure to sunlight is possibly a factor in causing cataracts. Eye cataracts are an **outcome**.

There is a **correlation / link** between exposure to sunlight and eye cataracts in the study. This means that people who are exposed to high levels of sunlight are more likely to develop cataracts.

However, it could be that the average age of those exposed to high levels of sunlight was greater than those exposed to low levels of sunlight. In addition, they may also have had a poor diet low in vitamins. Both these factors would decrease their ability to repair damage caused by ionising ultraviolet light.

The precautionary principle

The 'precautionary principle' tell you to avoid any activity if serious harm could arise. Parents may insist that their children are not allowed out on the beach at all in the summer months.

The **real risk** may be very different from the **perceived risk** ie the risk that you think is there.

You can't see ultraviolet, and the word 'radiation' sounds frightening to many people. This makes the risk seem worse than something you can see, and which is more familiar

Some parents may assume that summers are no different from when they were young, so there is no danger to their children

Other parents may be very alarmed by stories of increases in skin cancer, and not let their children out in sunny weather at all

Sometimes risk should be regulated by governments and other public bodies. This usually applies to an organisation, which is responsible for its employees. In some situations this may be controversial.

Question: If this is the case, can we say that high levels of sunlight cause cancer? Or is there another causal link?

Question: A person with dark skin moves to a live in a region where there are few sunny days. Why should they try to spend a lot of time out of doors?

Question: Exposure to sunlight increases your risk of developing skin cancer. List some benefits of staying indoors and avoiding direct sunlight.

Question: Why do some people say that exposure to high intensity sunlight is not a direct causal link to developing skin cancer.

The electromagnetic spectrum and its uses

Frequency	Type of electromagnetic radiation	Typical use	Wavelength
Highest	Gamma radiation	Killing cancer cells	Shortest
	X-rays	Medical images of bones	
	Ultraviolet radiation	Sunbeds	
	Visible light	Seeing	
	Infrared radiation	Optical fibre communication	
	Microwaves	Cooking	
Lowest	Radio waves	Television signals	Longest

All types of electromagnetic radiation travel at exactly the same speed through a vacuum, 300,000 km/s.

Damaging to health

The ions produced when ionising radiation breaks up molecules can take part in other chemical reactions. If these chemical reactions are in cells of your body, the cells can die or become cancerous. This is the reason that ionising radiation can be damaging to health.

It is important to be able to assess the size of risk in any activity. No activity is completely safe. The consequence of too much ultraviolet – skin cancer – often does not appear until much later in life, so it doesn't seem a real risk to young people.

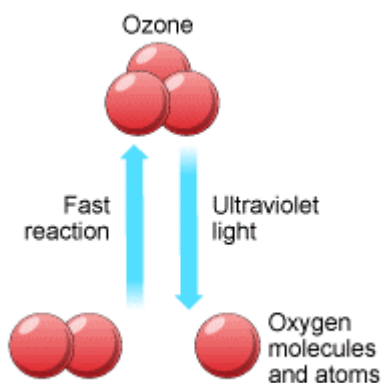
It is difficult to assess how much ultraviolet you are receiving when you are sunbathing. If you feel hot, that is because of the infrared, not the ultraviolet

One health risk, which is definitely present in our environment, is ultraviolet, in sunlight. Not much of the ultraviolet reaching the Earth gets to us, because the ozone layer high up in the atmosphere absorbs most of it. In the summer, it is wise to use sunscreens and clothing to absorb ultraviolet, and prevent it reaching the sensitive cells of the skin.

Question: Chemical pollutants released into the atmosphere such as Chlorofluorocarbons [CFCs] are breaking down the ozone layer. Why is this causing a health problem?

Scientific or technological developments often introduce new risks. Chemicals used in aerosol spray cans and fridges gradually made their way up to the ozone layer when released into the atmosphere, and removed some of it. This has increased the intensity of the **ultraviolet radiation** reaching the Earth. These chemicals are not used any more, and the ozone layer is gradually returning to normal. However, this will take a number of years more.

The ozone layer



Ozone molecule formation

The ozone layer absorbs ultraviolet because ultraviolet ionises the ozone, which then changes to oxygen. This chemical change is reversible, and the oxygen changes back to ozone.

Question: 'If it was not for photosynthesis we would have no protection against the harmful effects of ultraviolet light' explain what this statement means.

Absorption of radiation

All forms of electromagnetic radiation deliver energy. This will heat the material that absorbs the radiation. The amount of heating depends on the intensity of the radiation, and also the **length of time** the radiation is absorbed for. An object, which gives out electromagnetic radiation, is called a **source** of radiation. Something, which is affected by the radiation, is a **detector**.

Question: Complete the table using the text that follows:

How radiation can be absorbed	Effect of absorbing radiation
Metal aerials attached to radios and televisions can absorb microwaves and radio waves.	
Infrared radiation [heat energy] can be absorbed by the skin on our hands.	
The chlorophyll in plant leaf cells can absorb light energy.	
Cells can absorb gamma rays and this helps to produce a camera image.	

The vibrating radiation waves cause vibrating [alternating] electric currents in aerials.

If the light energy carries enough energy, chemicals are activated and glucose and oxygen is made.

The atoms in your hand vibrate more frequently and the hand gets warm.

Ionised atoms produce a clear image with the gamma camera.

Energy and intensity

Question: Complete the following text using the words that follow:

The intensity of _____ radiation is the energy arriving at a square metre of surface each second. This depends on two things: the energy in each _____, and the number of photons arriving each second.

To have the same _____, a beam of red light would need ten times as many photons as a beam of ultraviolet, and a beam of microwaves would need a million times as many.

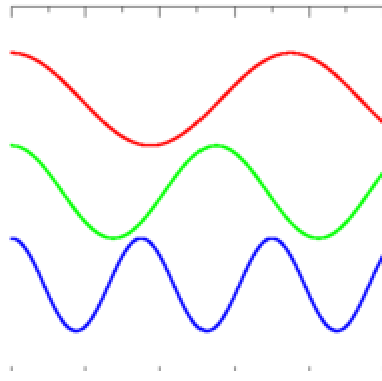
Energy of 1 ultraviolet photon = Energy of 10 red photons = Energy of 1,000,000 microwave photons

Radiations with the highest _____ have the photons with the highest energies. X-ray photons and _____ ray photons carry most energy. Radio photons carry least energy.

Sources of gamma rays, X-rays, and high energy UV radiation pack a lot of energy into each photon. A single photon has enough energy to ionise an atom or _____, by knocking off an electron. Gamma rays, X-rays, and some UV are ionising radiations.

Visible, infrared, microwave and radio _____ are all non-ionising radiations because a single photon does not have enough energy to ionise an atom or molecule. The main effect of these radiations is warming. The lower the photon _____ is, the smaller the heating effect of each photon.

Possible words: electromagnetic, photon, intensity, frequencies, radiations, molecule, energy, gamma.



The heating effect increases if:

- The intensity of the microwave beam is increased
- The microwave beam is directed onto the material for longer.

Radiation that is not absorbed by the atmosphere reaches the Earth's surface and warms it, leading to the greenhouse effect. Some radiation, such as ultraviolet, exposes our skin to harmful rays and puts us at risk of developing skin cancer.

Effects of microwaves

Question: Complete the following text using the words that follow:

Microwave ovens work because the food contains water molecules, which are made to vibrate by the microwaves. This means that food absorbs _____ and gets hot. The microwaves cannot escape from the oven, because the metal case and the metal grid on the door reflect microwaves back into the oven.

Some people think that _____ phones, which transmit and receive microwaves, may be a _____ **risk**. Everyone does not accept this, as the intensity of the microwaves is too low to damage tissues by _____, and microwaves are not ionising. The _____ and fat in people are two absorbers of microwaves.

Any radiation absorbed by living cells can damage them by heating them. However, **ionising** _____ are more likely to damage living cells. This is because photons of ionising radiation deliver much more energy. They can easily kill cells, and can also cause cancer by _____ the **DNA** in the nucleus of a cell.

Possible words: microwaves, water, mobile, **health, radiations**, heating, damaging.

Question: Complete the following text using the words that follow:

The heating effect depends on the intensity of the _____ and its duration [exposure time]. So you need to cook food for longer in a less powerful microwave oven. This is why they have power ratings, and food labels _____ different cooking times depending on this.

Mobile _____ use microwave radiation to send signals to send signals back and forth to the nearby phone mast. When you make a call, the fairly thick bones of your skull absorb some of this radiation. But some reaches your brain and warms it, ever so slightly. Vigorous _____ has a greater heating effect.

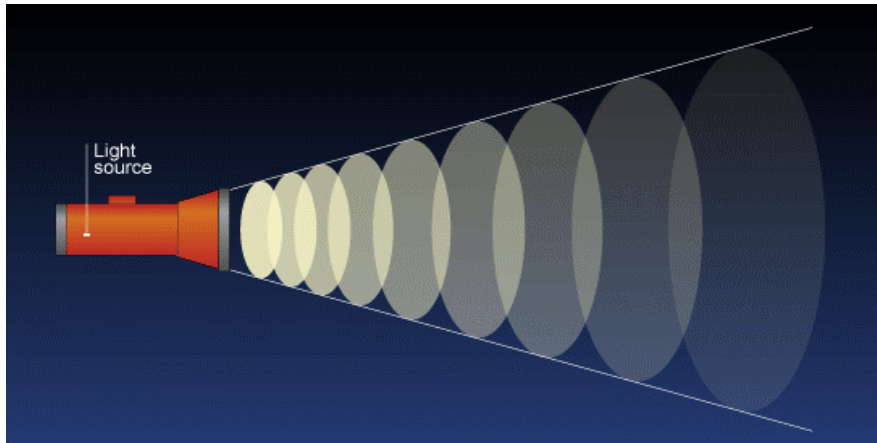
There is no _____ that this exposure is harmful. Some people use a hands free kit. The radiation is less intense because it spreads out from the phone.

As the photons spread out from the source, they are more thinly spread out when they reach the detector. The intensity may also decrease with distance due to partial _____ by the medium it travels through.

Microwaves in the _____ may be harmful, but there is no agreement on this. They are not ionising, and so cannot cause cancer in the way that **ultraviolet, X-rays** or **gamma rays** do.

Possible words: radiation, phones, exercise, recommend, evidence, absorption, environment.

The hotter an object is the more electromagnetic radiation is emitted. Even objects below 0°C emit weak infrared radiation of a low frequency.



As the temperature of an object increases, the higher the frequency of the radiation it emits. Very hot objects, such as the hottest stars, emit radiation whose principle or main frequency is in the ultraviolet region of the electromagnetic spectrum.

Question: What radiations are on either side of microwave radiation in the electromagnetic spectrum?

Question: Why doesn't microwave radiation cause ionisation?

Question: Why is it important that the walls and door of a microwave oven reflect the microwave radiation?

Question: Many people imagine that it is dangerous to live close to a mobile phone mast. Why might your exposure to microwave radiation from your phone be reduced if you lived close to a mast?

Question: The damage caused by radiation depends on the energy of the photons. Energy of photons of electromagnetic radiation is directly proportional to the frequency of the radiation. Explain what is meant by 'proportional to'.

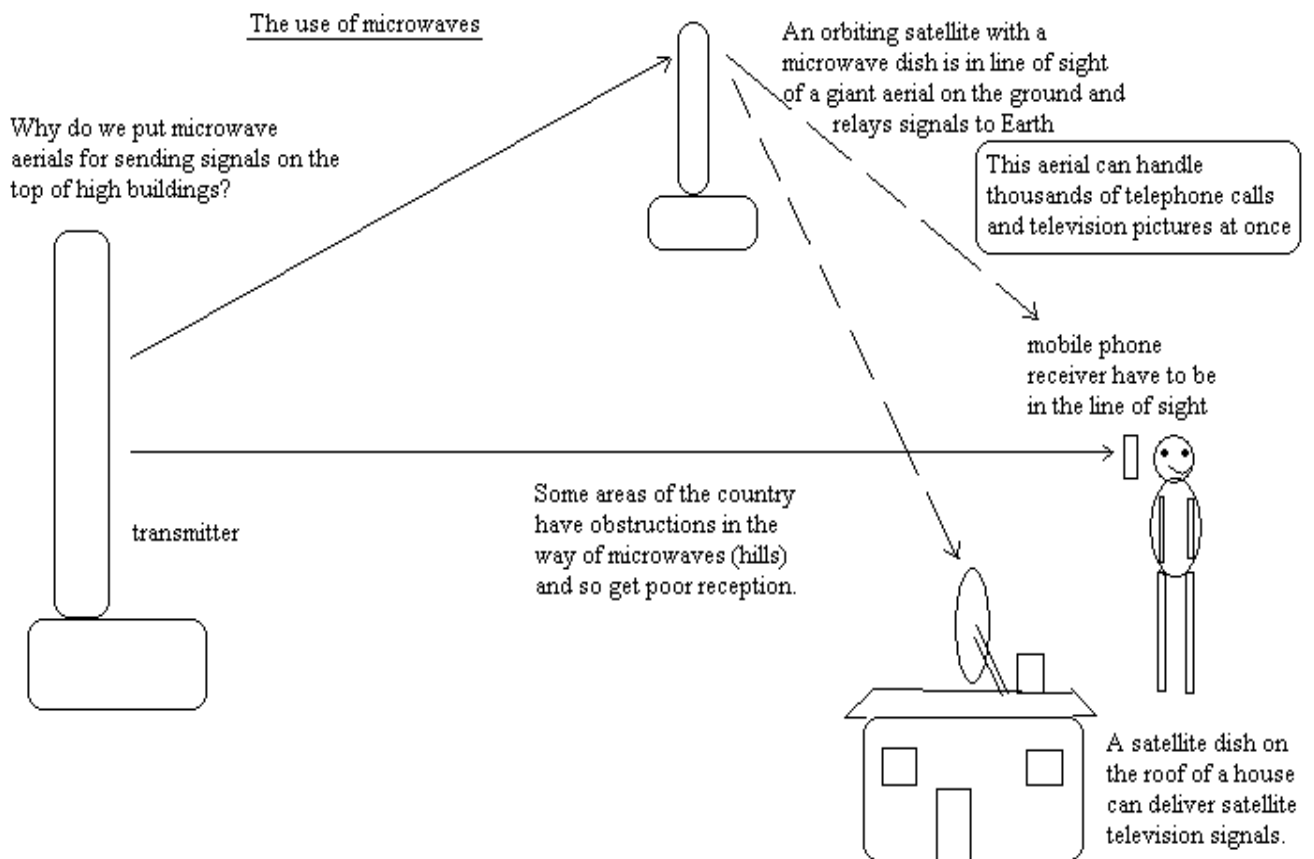
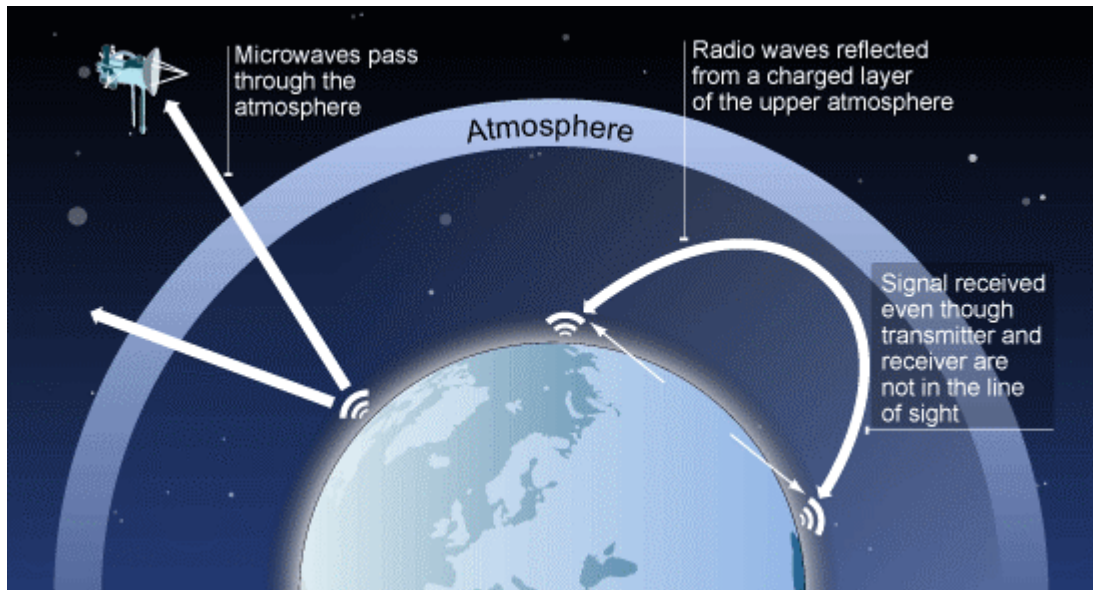
Communicating using waves

All types of mobile phone receive and send microwaves. These are radio waves with the highest frequencies. When communicating by mobile phone, sound is converted to microwaves. These are sent to mobile phone masts, which amplify and direct the signal to other mobile phones.

Even within the band of waves called microwaves, the wavelength can be different. Radio waves and micro waves travel for long distances because the atmosphere only weakly absorbs them.

The shortest wavelength for microwaves is 1mm and the longest is 30cm. Microwaves used for communication have a longer wavelength than those used for cooking.

This means that there is less energy transferred by mobile phones than by microwave ovens.



Question: Some research has shown that microwaves can cause a small heating effect in the brain. This in turn may / may not cause brain tumours. Explain how this may occur.

Microwaves can be transmitted over very large distances in straight lines between the transmitter (phone) and the receiver (mast). Over large distances this may not be possible because:

- (1) Mountains in the way
- (2) Curvature of the Earth prevents direct line of sight.
- (3) Poor weather conditions and large surfaces of water absorb microwaves.

Question: Complete the following text using the words that follow:

Microwaves are used for communication as well as for _____.

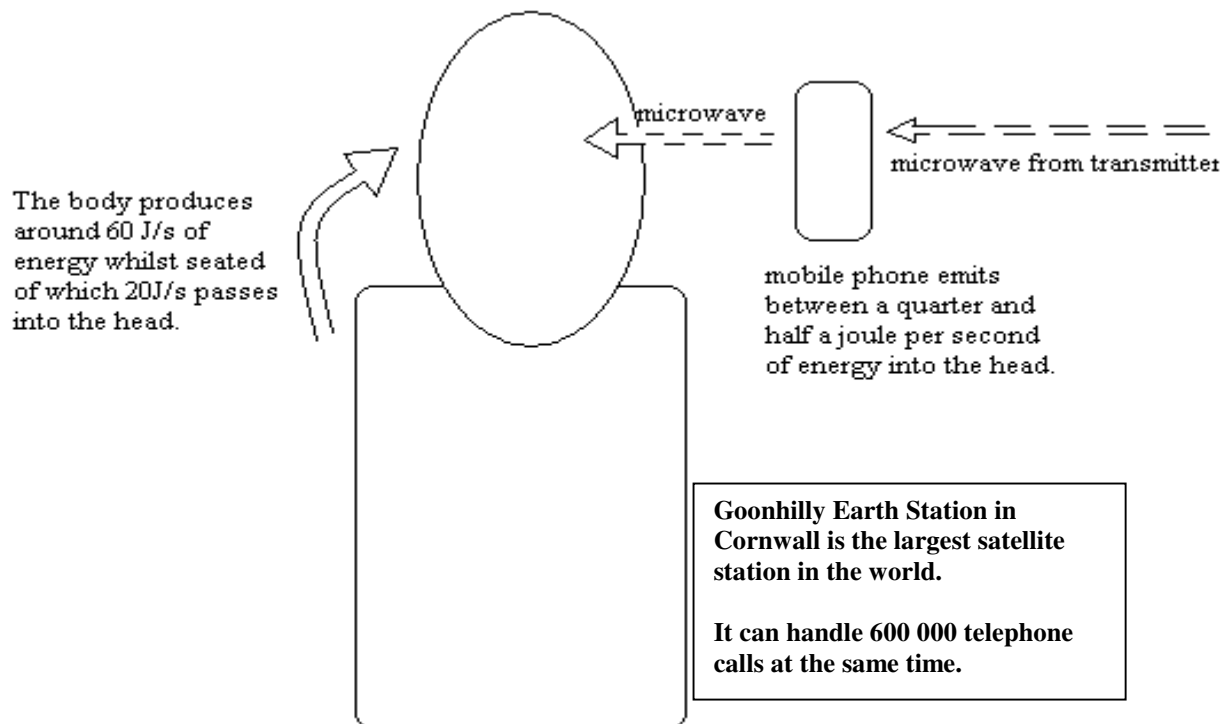
Recently there have been many reports about the dangers of _____ phones.

There is no scientific proof that mobile phone radiation 'cooks' the _____. There is some evidence of warming and _____ show signs of stress near mobile phones.

Young people use mobile phones a lot and their brains are still developing.

The _____ advises that young people should not use mobile phones for 'non-essential' calls.

Possible words: rats, brain, mobile, cooking, government.



Diffraction

Diffraction occurs when a wave hits the edge of a harder substance and is deflected from its path. Microwaves do not exhibit very much diffraction around natural objects such as hills.

This is why sometimes the reception on mobile changes from maximum to zero in a very short distance.

Interference

Mobile phones are banned in most hospitals because there is evidence that the microwave signals can interfere with sensitive medical equipment. However, many doctors feel that the benefits of having mobile phones outweigh the risks.

Question: Suggest why aerials for mobile phone signals are placed close together in towns.

Question: Suggest why mobile phones should not be used on aeroplanes.

Question: Why does the government advise young people to use mobile phones for essential calls only?

Question: The door of a microwave oven is made from special glass that does not allow microwaves to pass through. Suggest why.

Question: How does the wavelength of infrared from a glowing coal fire compare to that of infrared from a human being?

Many people are worried about where mobile phone masts are situated. There are concerns about the possible risks of cancer due to microwave radiation. Masts should not be situated near schools or playgrounds.

Question: Why are microwave aerials placed on very tall buildings?

Question: Suggest why mobile phone masts should not be sited near to a children's play area.

Gamma radiation and X-rays

Gamma radiation

Gamma waves have a very high *frequency*. Gamma radiation cannot be seen or felt. It mostly passes through skin and soft tissue, but cells absorb some of it.

Gamma radiation is used, among other things, for the following purposes.

- To sterilise surgical instruments
- To kill harmful bacteria in food
- To kill cancer cells (note that lower doses of gamma radiation could lead to cells becoming cancerous)

X-rays



Chest X-ray

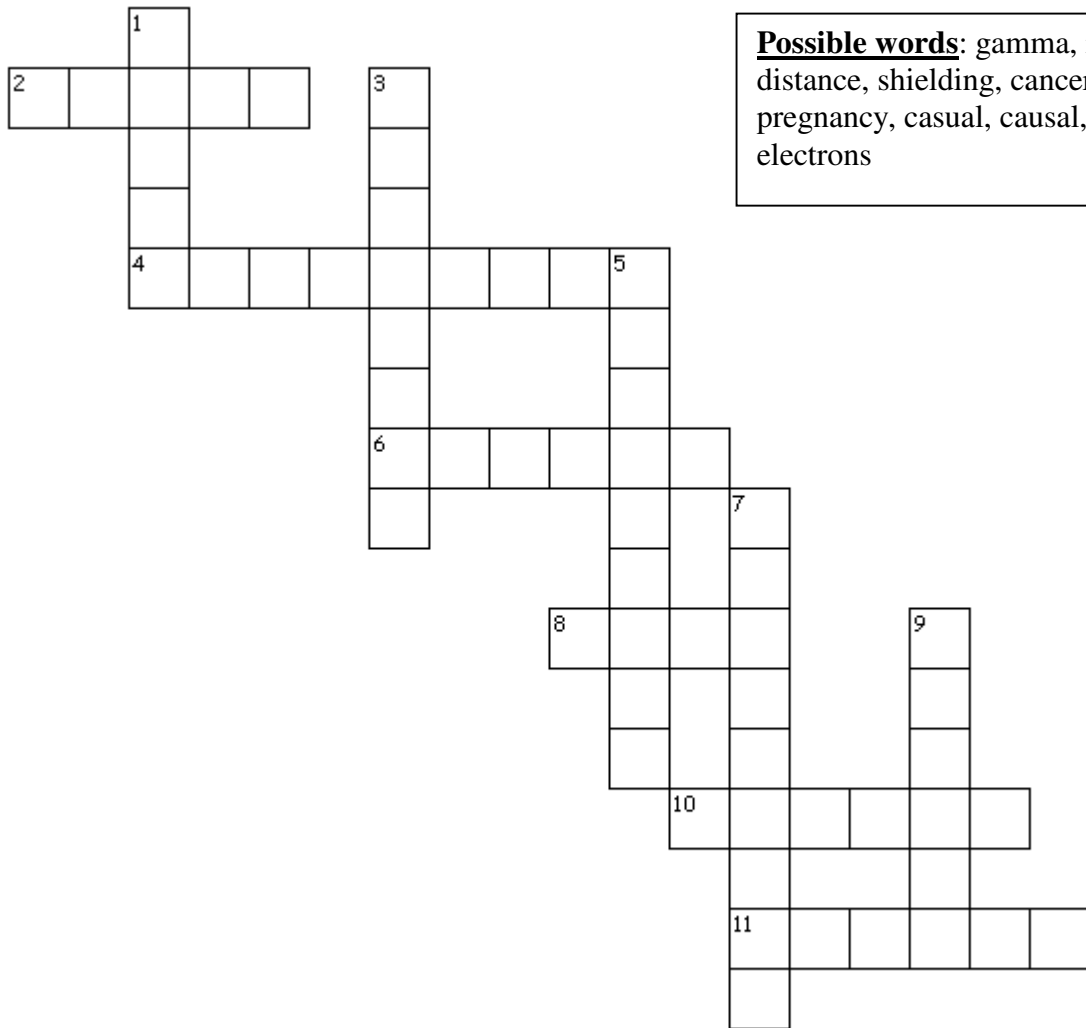
X-rays have a lower frequency than gamma radiation. Like gamma rays, they cannot be seen or felt. X-rays mostly pass through skin and soft tissue, but they do not easily pass through bone or metal. X-rays are used to produce photographs of bones to check for damage such as fractures. They are also used in industry to check metal components and welds for cracks or other damage. Lower doses of X-rays can cause cells to become cancerous, so precautions are taken in hospitals to limit the dose received by patients and staff when X-ray photographs are taken.

X-ray photons can ionise molecules in your body, and this is particularly risky if DNA molecules are affected leading to cancer.

Studies have shown there to be a correlation / link between X-ray exposure of mothers during pregnancy and cancers in their children.

Question: The radiation is more damaging to cells that are rapidly dividing. In your opinion is this correlation a causal link or a casual one? Explain.

X-ray Crossword



Possible words: gamma, image, distance, shielding, cancer, time, pregnancy, casual, causal, organs, electrons

Across

2. These photons are similar to X-rays but come from radioactive sources.
4. X-rays photons are produced when these strike metals.
6. X-rays can ionise the atoms in DNA and cause this.
8. The shorter the exposure _____ to X-rays the less radiation is absorbed so the smaller the chance of damage to cells.
10. When there appears to be a link between two variables but one variable does not appear to cause the other.
11. When there appears to be a link between two variables because one variable is causing the other.

Down

1. Badges that are sensitive to X-rays need to be worn by X-ray workers which produce this to warn them of dangerous exposure.
3. if you keep this large between an X-ray source and yourself, you will be safe because the intensity decreases as it spreads out.
5. Materials such as lead need to be positioned between the X-ray technician and the machine to act as shielding and absorb the radiation.
7. During this the foetus contains actively dividing cells, which absorb X-rays more strongly.
9. Both X-rays and gamma rays can be used to see images of these in the body.

Analogue versus digital communication

Analogue signals

When a person speaks into a microphone connected to an oscilloscope an analogue wave pattern is seen on the screen. The pattern represents the sound energy changes occurring as he speaks.

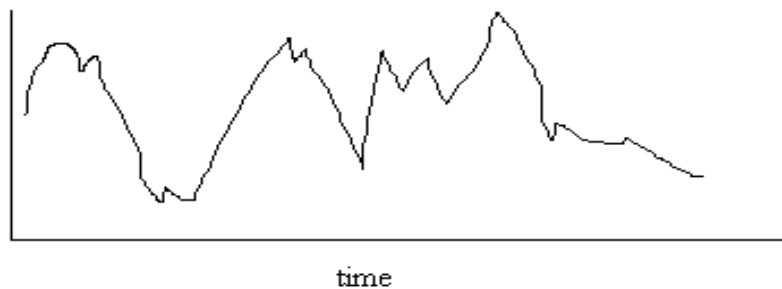
Even humming a note produces a complicated wave pattern. The wave pattern is interpreted as follows:

Height of wave indicates loudness

Distance between waves indicates pitch. High pitch sounds have waves close together (many cycles / vibrations per second = high frequency).

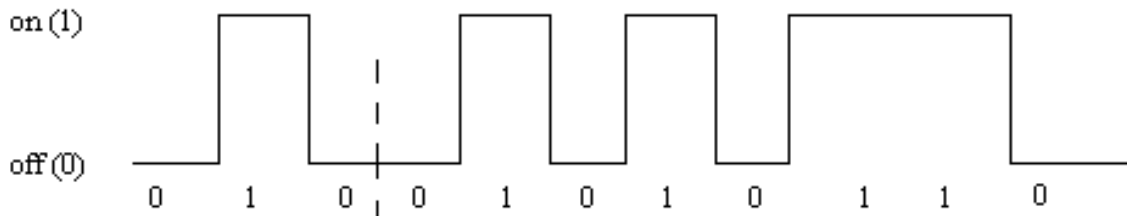
An analogue value can have any value. It is continuously variable.

Intensity
(strength) of
analogue signal
can be any value

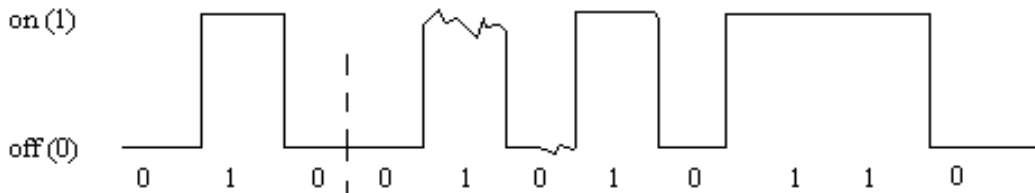


Digital signals

A digital signal can only have two values, on or off. On is represented by 1 (or high) and off by 0 (or low).



When a digital signal is transmitted it too can have interference. However, because all the receiver detects is either a high or low digital signal, the interference is not apparent in the final output. A TV remote sends a digital signal to your television when you change channel. Inside the remote there is a small infrared light, this rapidly flashes on and off.



Question: What do you notice about the above digital wave?

Question: A wristwatch has hands and numbers 1 to 12.

Explain why it is described as an analogue watch. How is it different to a digital watch?

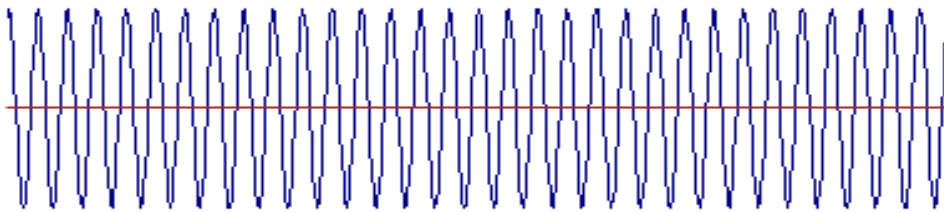
Interference, Refraction and Reflection

When an analogue radio wave is to be transmitted, interference can occur. First of all a radio wave is produced with the same frequency as a speaking person e.g. 200Hz. This is then superimposed over a carrier wave of typical frequency 200 000Hz.

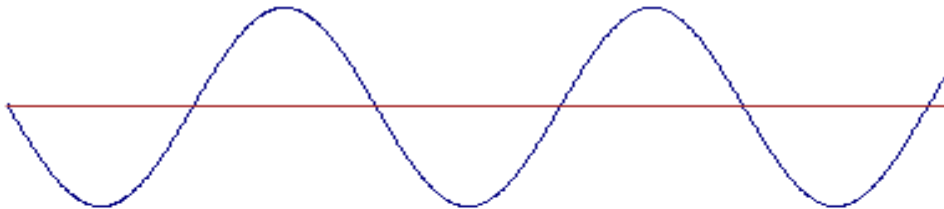
Wireless signals (electromagnetic waves) can be reflected and refracted by buildings or by layers in the atmosphere. This can cause the signal to lose energy and become weak. Too many reflections can cause a drop in quality because the wireless appliance receives more than one signal at once. If radio stations transmit on similar frequencies a similar effect is seen as the different waves interfere with each other

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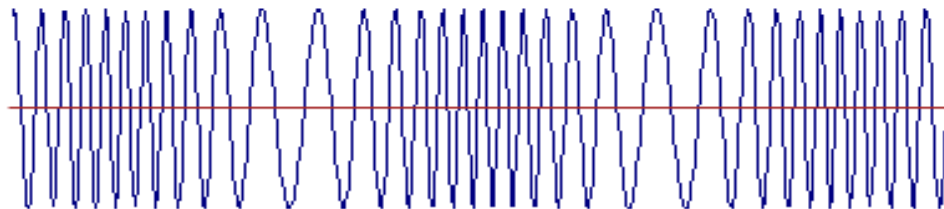
Carrier



Modulating Wave



Modulated Result



The modulating wave is that of the same frequency of the voice being transmitted. A receiver subtracts the carrier wave so that the original wave can be reproduced.

Sometimes another interference wave superimposes over the original modulating wave representing the man's voice as below.

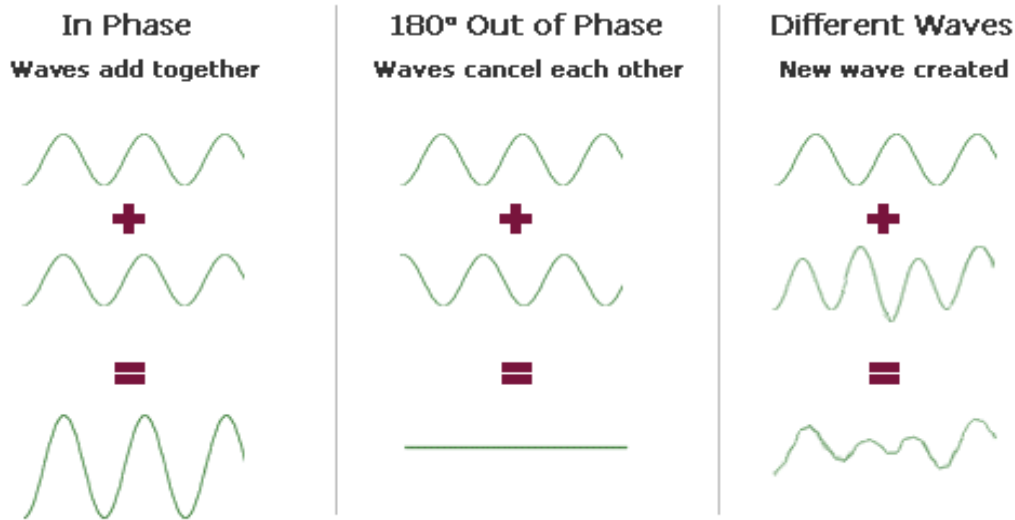
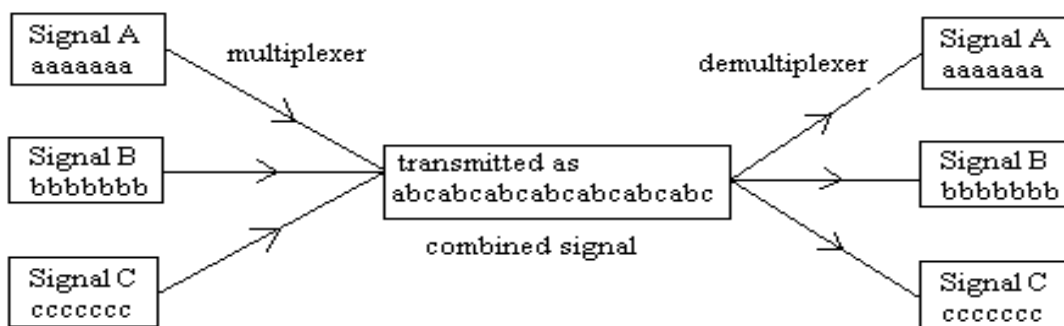


Image courtesy of www.mediacollege.com

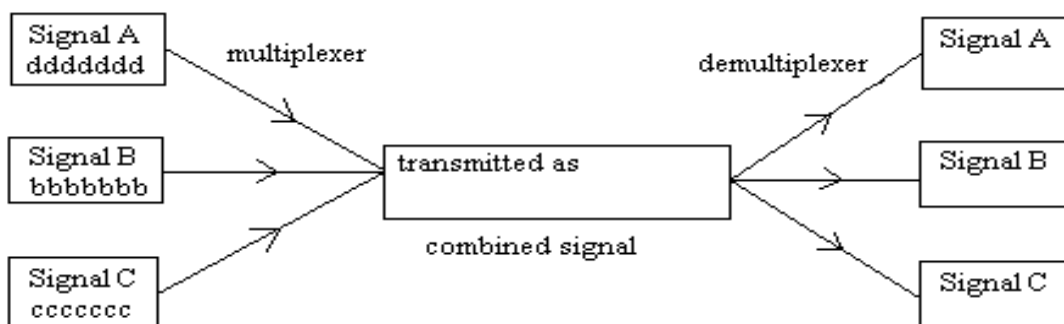
This is then carried by the carrier analogue wave and the receiver separates off this new 'hybrid' wave that contains interference. The receiver cannot go one stage further and separate away the interfering wave from the modulating wave representing the man's voice

Multiplexing

Multiplexing allows many different digital signals to be transmitted simultaneously. Each digital signal is divided into segments of very short duration. A combined signal takes each segment in turn and transmits it. A multiplexer produces this combined signal and a demultiplexer separates them at the receiving end of the transmission. This allows more information to be sent at any given time. This is why you get more channels on digital television.



Question: Complete the example below yourself



Question: What is the advantage of multiplexing?

Question: Give two advantages of transmitting a digital signal rather than an analogue signal.

DAB radio

In some parts of the world, FM radio is being challenged by the introduction of digital audio broadcasting radio (or DAB radio for short).

Advantages	Disadvantages
More stations available	Not all areas of the UK are covered
Less chance of interference with other stations, so a clearer signal	Sometimes the sound quality is not as good as FM. This is because the sound is compressed like an mp3 file.

Using infrared

Question: Complete the following text using the words that follow:

Infrared waves can be used to _____, but only over much shorter distances. Most remote controls use infrared to send a signal from the remote to the TV. There is a small infrared light at the end of the remote. This _____ on and off and special _____ in the TV detect this signal. A similar technique can be used to send data to and from some laptops or mobile phones. Both are examples of _____ signals.

Infrared sensors can also be used to detect body heat. This can make them very useful for _____ alarms and automatic security lighting.

The digital signal sent from the _____ is in the form of a coded series of flashes. A special sequence will cause the TV to change channel, a different sequence increases the volume. Only certain codes work with certain devices. This is why your TV remote has no effect on your _____.

Possible words: communicate, flashes, remote, sensors, burglar, stereo, digital

Question: Describe the differences between an analogue and a digital signal.

Question: Explain the advantages of transmitting a digital television signal rather than an analogue one

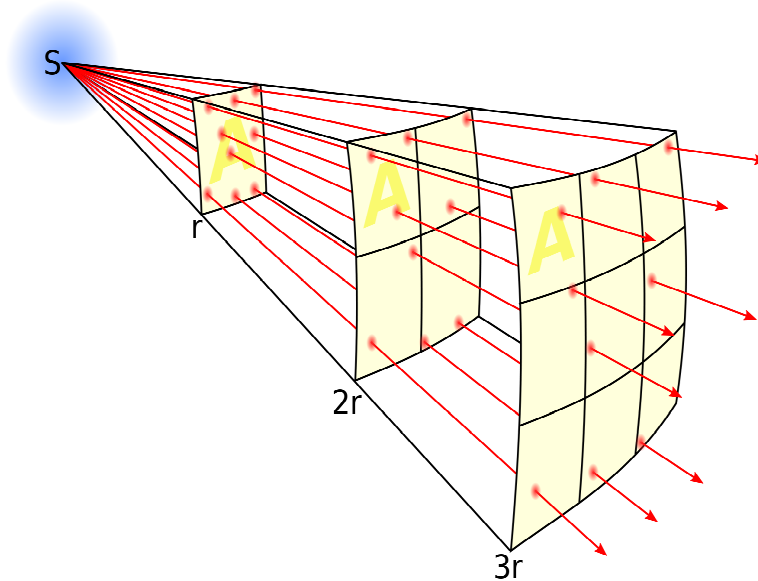
Question: describe how infrared radiation is used in remote controls.

Optical fibres

Information such as computer data and telephone calls can be converted into infrared signals and transmitted by **optical fibres**. Optical fibres are able to carry more information than an ordinary cable of the same thickness. In addition the signals they carry do not weaken so much over long distances. Television remote controls use infrared light to transmit coded signals to the television set in order to, for example, change channels or adjust the volume.

Is there a health risk to using microwaves as a means of communication?

A mobile phone sends out signals that are detected by a nearby mast. This is how the phone connects to the network.



Consider 'S' on this diagram to be the mobile phone [twice as far away, the area covered by the same intensity [same number of photons / second] is four times as great]. The further S is away from your ear, the less intense the microwave radiation your head receives [time of exposure is also a factor].

The number of microwave photons / second received by your head over a period of time directly affects the heating effect produced!

Question: What would your advice be to someone who has a mobile phone?

Similarly, the radiation from the mast is most intense as it leaves the phone masts. By the time it reaches a distant phone it is very weak. Furthermore, phone masts are designed so that their radiation is shaped like the beam of light from a lighthouse. If you stand directly under a mast, its radiation is much weaker than the radiation from your phone.

Question: What would you say to someone whose house is nearby to a mobile phone mast and they are worried about possible health problems arising from this?

Question: People living in a house nearby to a newly erected mobile phone mast may have no choice but to remain living there. They have heard of possible health risks and may even be aware that there is no conclusive causal link proven between microwaves and cancer risks.

Do you think people overestimate risks when [a] the cause [microwaves] is invisible and the effects [cancer] unseen? [b] They are not in control of the situation/

Health studies

To look for harmful effects, scientists compare a sample of mobile phone users with a sample of non-users. Does one group show a higher rate of cancer for instance?

Things to consider when selecting the two groups

This has to be a fair test. We want to see if there is a causal link between one variable [intensity of microwaves] and another [frequency of people getting cancer]

Problem: There are many causes of getting cancer. We want to provide fair testing conditions between the two groups so that any cancer observed must have been the result of microwaves.

Question: Cancer can be caused by a number of factors. For each explain how you would control this variable within the two test groups:

[1] Age:

[2] Lifestyle [eating, smoking, alcohol]

[3] Inherited cancers

[4] Viruses

Question: Would it be a good idea to have large or small sample sizes? Explain [hint think of the effect of random chance on the percentage getting cancer].

How great is the risk?

Imagine the risk of developing eye cataracts in normal levels of sunlight were 1 in 1 million.

Now risks are often reported as being 'relative' i.e. when compared to the normal situation.

Question: Imagine that it was reported that ‘The risk of developing eye cataracts increases by four times in high levels of sunlight’

Exactly what is the probability of this happening?

Would this cause you to change your lifestyle?

Remember, this is an average estimate [some people due to genetics] may be more susceptible.

Climate change

The atmosphere absorbs some radiation of the electromagnetic spectrum, but some is transmitted.

Light, some infrared, some *ultraviolet*, and *microwaves*, pass through the atmosphere and reaches the Earth’s surface. *Gamma rays*, *X-rays*, most of the ultraviolet and some of the *infrared* are absorbed by the atmosphere and do not reach the Earth’s surface.

Infrared from the Sun reaches the Earth’s surface and warms it. The warm Earth emits some infrared radiation, and gases in the atmosphere absorb some of this [methane, carbon dioxide and water vapour]..

This is called the greenhouse effect. If there were no greenhouse effect, the Earth would be too cold for life, as we know it.

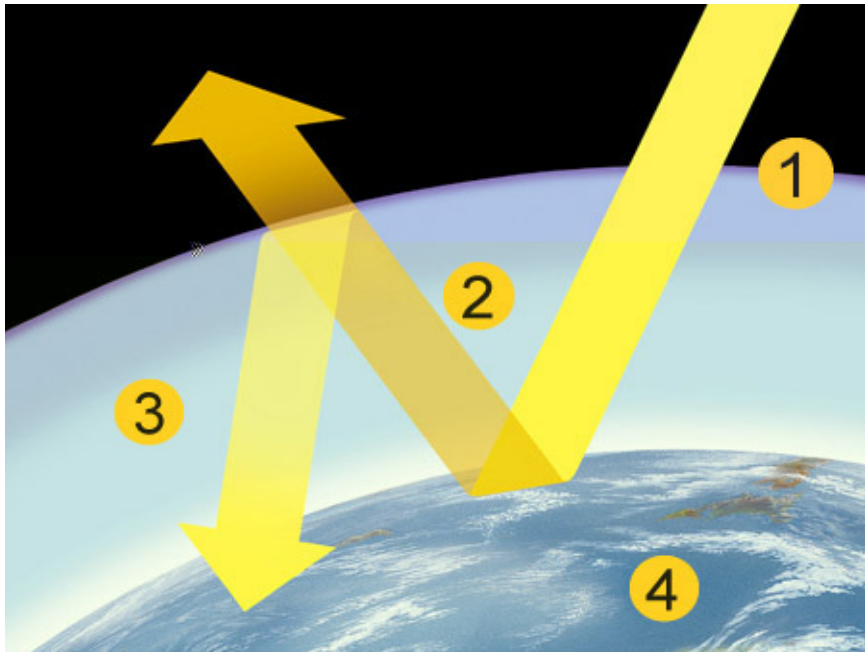
Light from the Sun reaching the Earth’s surface provides the energy for plants to produce food by *photosynthesis*. Photosynthesis replaces carbon dioxide in the atmosphere with oxygen. This reverses the process of respiration

Global warming

Types of radiation from the electromagnetic spectrum make life on Earth possible, but some have hazards associated with them. These hazards need to be carefully considered, and the evidence weighed up in order to reach a scientific explanation.

Greenhouse gases

Some gases in the Earth’s atmosphere absorb *infrared radiation*. One of these is carbon dioxide. Even though carbon dioxide is only about 0.04 per cent of the atmosphere, it is a very important greenhouse gas because it absorbs infrared well.



Greenhouse effect

Question: Number these statements so that they correspond to the numbers in the diagram.

- The Sun's rays enter the Earth's atmosphere
- Heat is emitted back from the Earth's surface at a lower principal frequency than that emitted by the Sun [longer wavelength].
- Some heat passes back out into space
- But some heat [longer wavelength infra red] is absorbed by carbon dioxide, a greenhouse gas, and becomes trapped within the Earth's atmosphere. The Earth becomes hotter.

Water vapour and methane

Other greenhouse gases are water vapour, and also methane. Even though methane is present in trace (tiny) amounts only, it is a very efficient absorber of infrared.

The carbon cycle

The amount of carbon dioxide in the atmosphere is controlled by the carbon cycle.

Processes that remove carbon dioxide from the air:

- *Photosynthesis* by plants
- Dissolving in the oceans.

Processes that return carbon dioxide from the air:

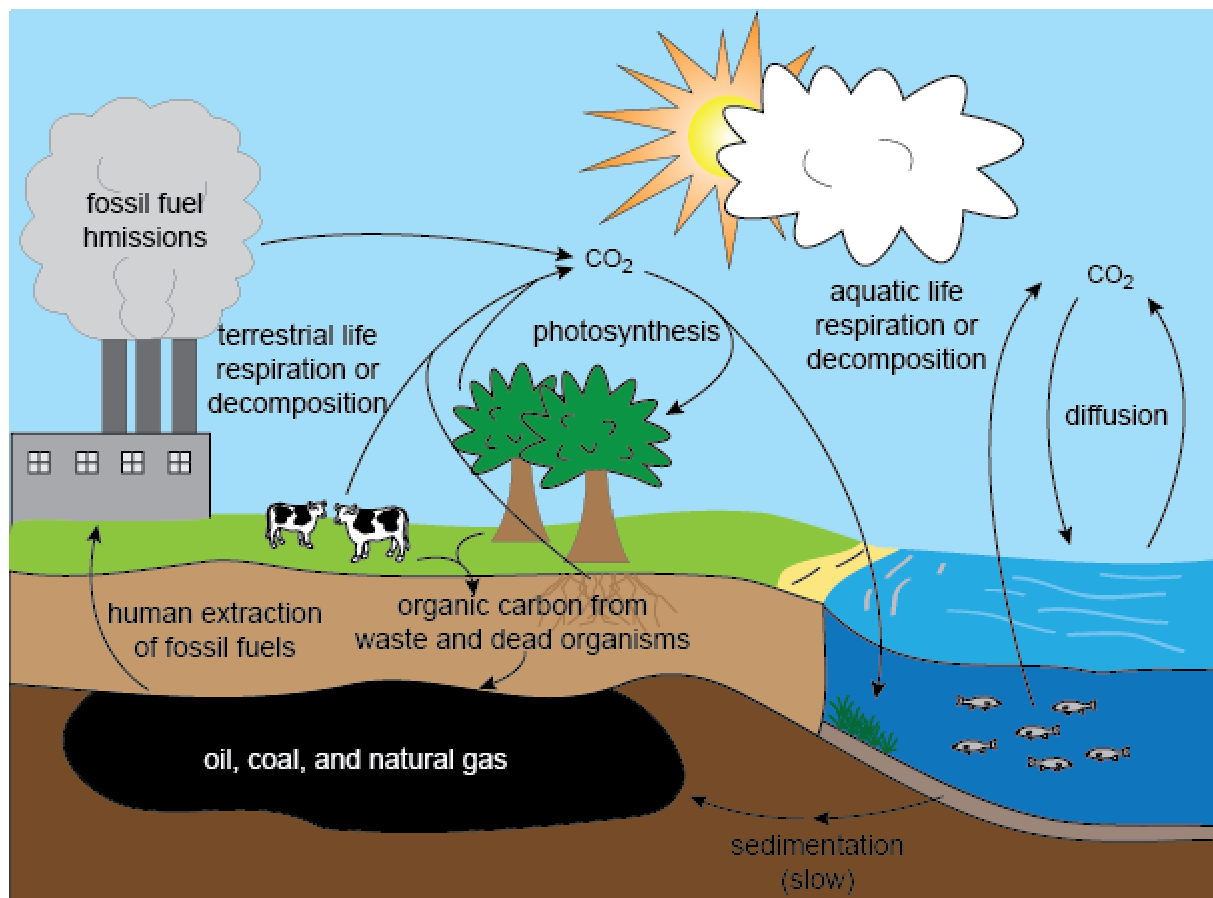
- *Respiration* by plants, animals and microbes
- Combustion ie burning wood and fossil fuels such as coal, oil and gas
- Thermal decomposition of limestone, for example, in the manufacture of iron, steel and cement.

All cells contain carbon, because they all contain proteins, fats and carbohydrates. For example, plant cell walls are made of **cellulose**, a carbohydrate.

Decomposers, such as microbes and fungi, play an important role in the carbon cycle. They break down the remains of dead plants and animals. This releases carbon dioxide through respiration.

For thousands of years, the processes in the carbon cycle were constant, so the percentage of carbon dioxide in the atmosphere did not change. Over the past 200 years, the percentage of carbon dioxide in the atmosphere has increased steadily because humans are:

- Burning more and more fossil fuels as energy sources
- Burning large areas of forests to clear land, which means that there is less photosynthesis removing carbon dioxide from the air.



Although the changes have been gradual, most - but not all - scientists agree that the climate is getting gradually warmer. This is called **global warming**.

Most - but not all - scientists lay the blame for this on human activities increasing the amount of carbon dioxide in the atmosphere.

Global warming could cause:

- Climate change
- Extreme weather conditions in some areas.

Climate change may make it impossible to grow certain food crops in some regions. Melting polar ice, and the thermal expansion of seawater, could cause rising sea levels and the flooding of low-lying land. Extreme weather events become more likely due to increased convection accompanied by more water vapour being present in the hotter atmosphere.

Question: Consider the diagram of the Carbon Cycle on the last page: Explain what happens in this cycle in your own words. Include manmade global warming effects. You need to include:

- Six processes that release CO₂ into the atmosphere.
- Two processes that remove CO₂ from the atmosphere.
- Two manmade processes that have led to an increase in the levels of atmospheric CO₂

Computer climate models

One piece of evidence that supports the view of scientists who blame human activities for global warming has been provided by 'supercomputers'. Computer generated climate models, based on different amounts of carbon dioxide in the atmosphere, produce the same changes as have been observed in the real world.

Ideas about science – correlation and cause

The ideas of correlation and cause are illustrated with the evidence for *global warming*.

Any process can be thought of in terms of factors that may affect an **outcome**. In global warming, one factor is the amount of carbon dioxide in the air. The outcome is the mean air temperature.

Establishing a correlation

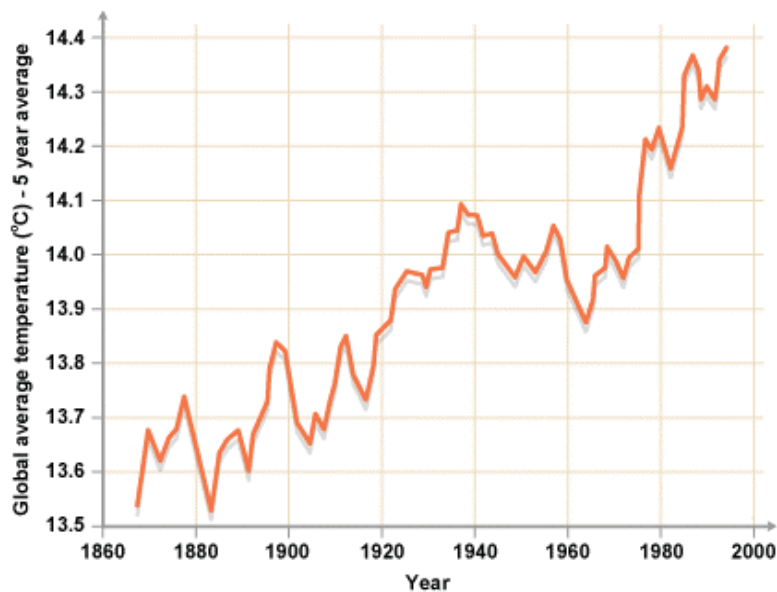
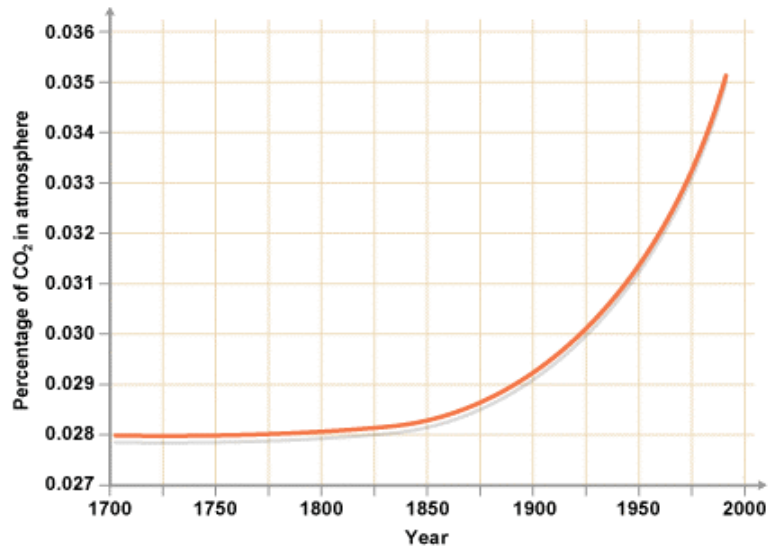
To establish a correlation between a factor and an outcome, convincing **evidence** is needed. This usually means that enough data must be collected, and that different samples should match.

Question: Compare the following two graphs on the next page and consider these questions:

[a] Are the changes reported significantly large? [Explain]

[b] Are they properly matched in terms of the times over which they are reported?

[c] Do these two graphs match well enough?



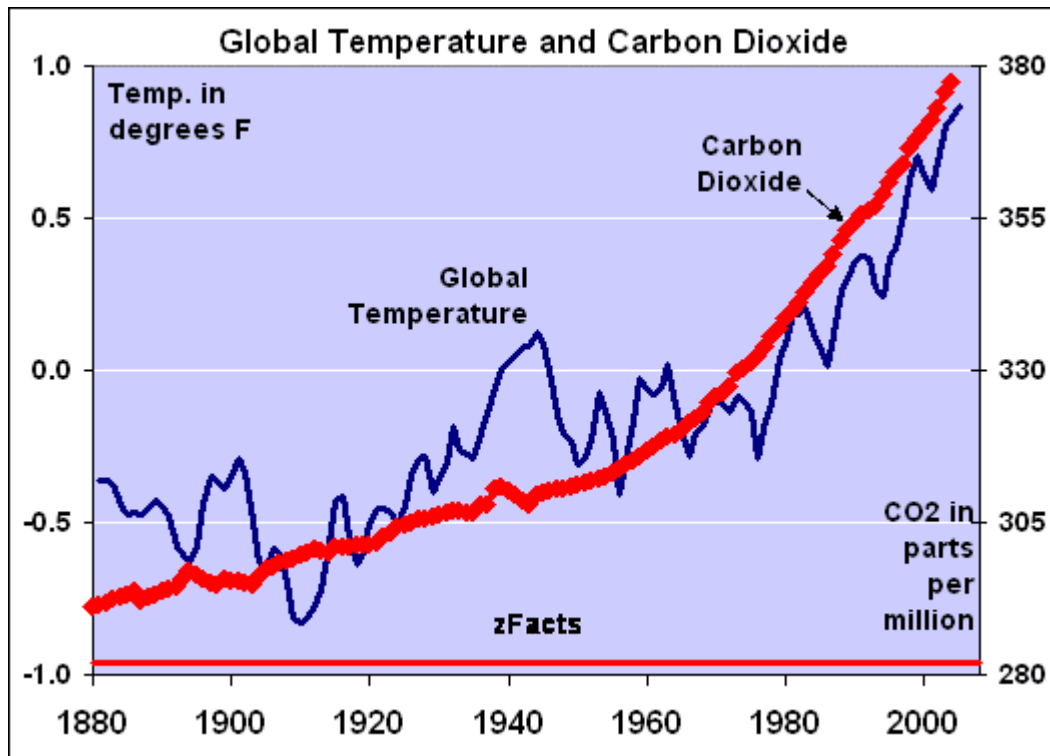
The graphs show a clear pattern. The Earth's average temperature has been rising since 1800. This conclusion is supported by evidence from Nature's own records [growth rings in trees, ocean sediments, air trapped in ancient ice].

Most scientists think that carbon dioxide [CO₂] in the atmosphere is causing the rise in temperatures. Why?

- Temperatures and CO₂ levels have risen at the same time.
- Evidence from the distant past suggests that temperature and CO₂ levels go up and down together [ice in Antarctic that contains trapped air, which is thousands of years old. It shows that the climate has always changed. With periodic ice ages and warm periods linked to the fossil record]
- Scientists can explain how CO₂ in the atmosphere absorbs radiation and raises the temperature.

Question: Explain why the carbon dioxide levels could have risen so drastically since 1860 [include the effects of deforestation].

Question: Personal experience does not provide reliable evidence of climate change. Why not?



Changes to the weather can have human and natural causes

As the global temperatures increase, the polar ice caps will melt. Seawater will expand in volume and the sea level will rise flooding smaller islands and leaving less land on which people can live and grow crops.

The remaining food crops will also struggle to grow. More water will evaporate leaving the soil dry and drought conditions will prevail. There will be more frequent hurricanes to destroy these crops. Hurricanes form over warm water – so with more warm water, you would expect more hurricanes.

Soot and gases produced by factories will reflect heat from cities back down to Earth increasing global warming.

Question: As well as global warming produced by mankind; we might be doubly unlucky if this also coincides with a natural global warming phenomenon.

Explain how this might be caused by:

- (a) Ash and gases thrown into the atmosphere by volcanoes
- (b) Changes in the orbit round the Sun

Changing the future

Natural factors have in the past caused climate change:

- The Earth's orbit changes the distance to the Sun by small amounts
- The amount of radiation from the Sun changes in cycles
- Volcanic eruptions increase atmospheric CO₂ levels.

These factors cause much slower changes than expected, but they must be taken into account when scientists try to determine whether human activities are causing the climate to change.

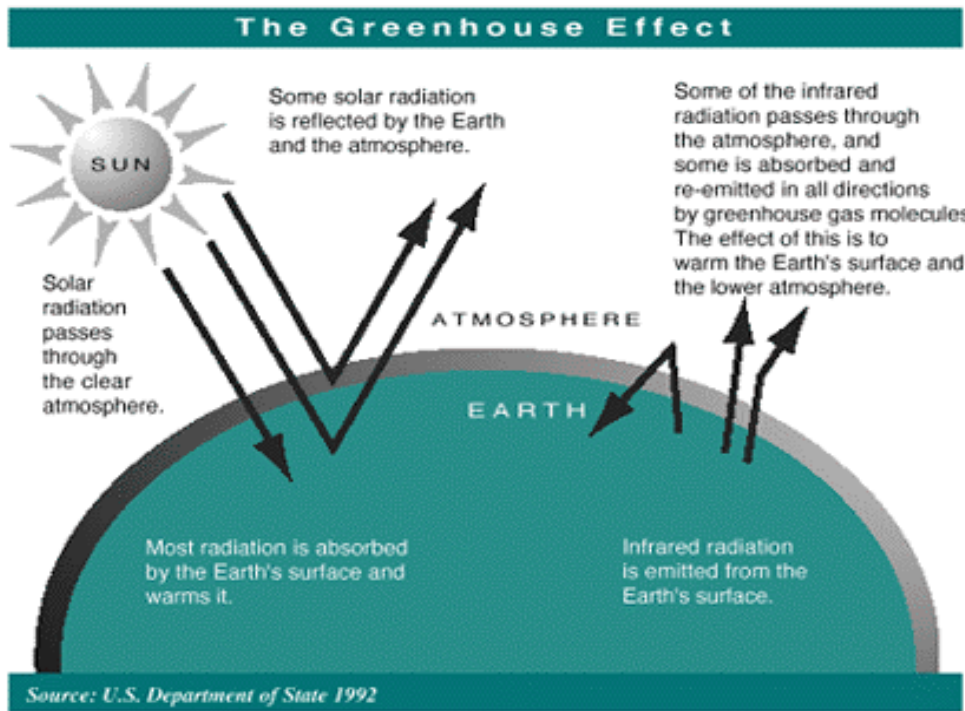
Question: Explain how each of these natural effects could cause a global warming effect.

Other greenhouse gases

(1) Methane: Methane molecules absorb and then radiate back down to Earth, twenty times more infrared than CO₂ molecules. This gas is produced by cattle and during the microbial decomposition of waste in landfill sites. Volcanoes, wetlands and wild animals also produce it naturally.

(2) Water vapour: As the global temperature increases, so does the evaporation of water vapour into the air. These molecules in turn act to increase global warming because they are significant greenhouse gases. Power stations also produce water vapour, which can affect the amount in the local area.

Question: As the frozen arctic tundra melts due to global warming, microbes will be able to feed on and carry out respiration (CO₂) and fermentation (methane) on organic matter in the ground. Even if we stop releasing CO₂ by burning fossil fuels, it may be too late to stop this from happening. Explain what might then happen.



Scientists use climate models to predict the effects of increasing CO₂ levels.

Computer programs are given the following data:

- The Earth absorbs 1% more energy from the Sun than it radiates back to space.
- This extra energy warms the oceans.
- It causes water to evaporate

The computer model should be able to calculate expected temperatures. These can be checked against known temperatures in the past.

Question: Once the program starts to calculate expected climatic temperatures from known data and it is confirmed from past data, we can then predict future temperatures.

Human activities e.g. burning fossil fuels and deforestation will have the following predicted effects:

- 2 to 6⁰C rise in global temperatures in our lifetime.
- The rise may become irreversible.
- To stabilise temperatures, we need to reduce carbon emissions by 70% globally.
- In the UK winters will become wetter and summers drier.
- Ice will continue to melt and sea levels rise regardless of what we do for 300 years.

Question: Sea levels are rising. Give two reasons why they are likely to continue rising in the future.

Question: Explain why rising temperatures will give rise to more violent storms.

Question: Which two effects of global warming may make it difficult to grow some food crops in particular regions?

Question: Make a list of scientific uncertainties to the idea that recent global warming is man made. This is evidence, which is used by 'climate sceptics' who challenge that we are causing global warming.

Question: Why do people say that it is the Developed World e.g. Europe and America which is causing global warming whilst the Developing World e.g. Africa and Asia which is suffering the harmful effects?

The UK is at risk!

Question: In Britain, we experience warmer weather than expected in such a northerly latitude because of the Gulf Stream. This is a mass of warm air carried over a mass of moving water from the USA to Britain.

As the Arctic melts more and more with global warming and colder melted water starts to move southward pushing the Gulf Stream away from Britain, how might this affect our weather?

What can governments do?

We need to reduce greenhouse gas emissions and this means:

- Generating electricity without burning fossil fuels
- Developing fuels for cars that do not release carbon dioxide.

Question: governments are elected every 4 years. Why don't they make these changes immediately for the benefit of the planet?

Science to the rescue!

Question: there are several possible ways that we might solve the problem of global warming. Complete the following text using the words that follow:

- Spread iron granules on the _____ oceans. This would help the growth of plankton, which takes _____ carbon dioxide from the ocean. The oceans would then remove more carbon dioxide from the atmosphere.
- Capture the carbon dioxide produced at power stations. Then _____ it into a liquid and pump it into disused oil reservoirs beneath the sea.
- Cement _____ counts for 5% of the greenhouse gases produced in Europe and America and more than 10% in China. A new type of 'eco-cement' absorbs carbon dioxide whilst setting and goes on absorbing _____ dioxide for years afterwards.

Possible words: dissolved, compress, production, carbon, southern.

Question: Do you think that people should rely on technical solutions? Justify your answer.
