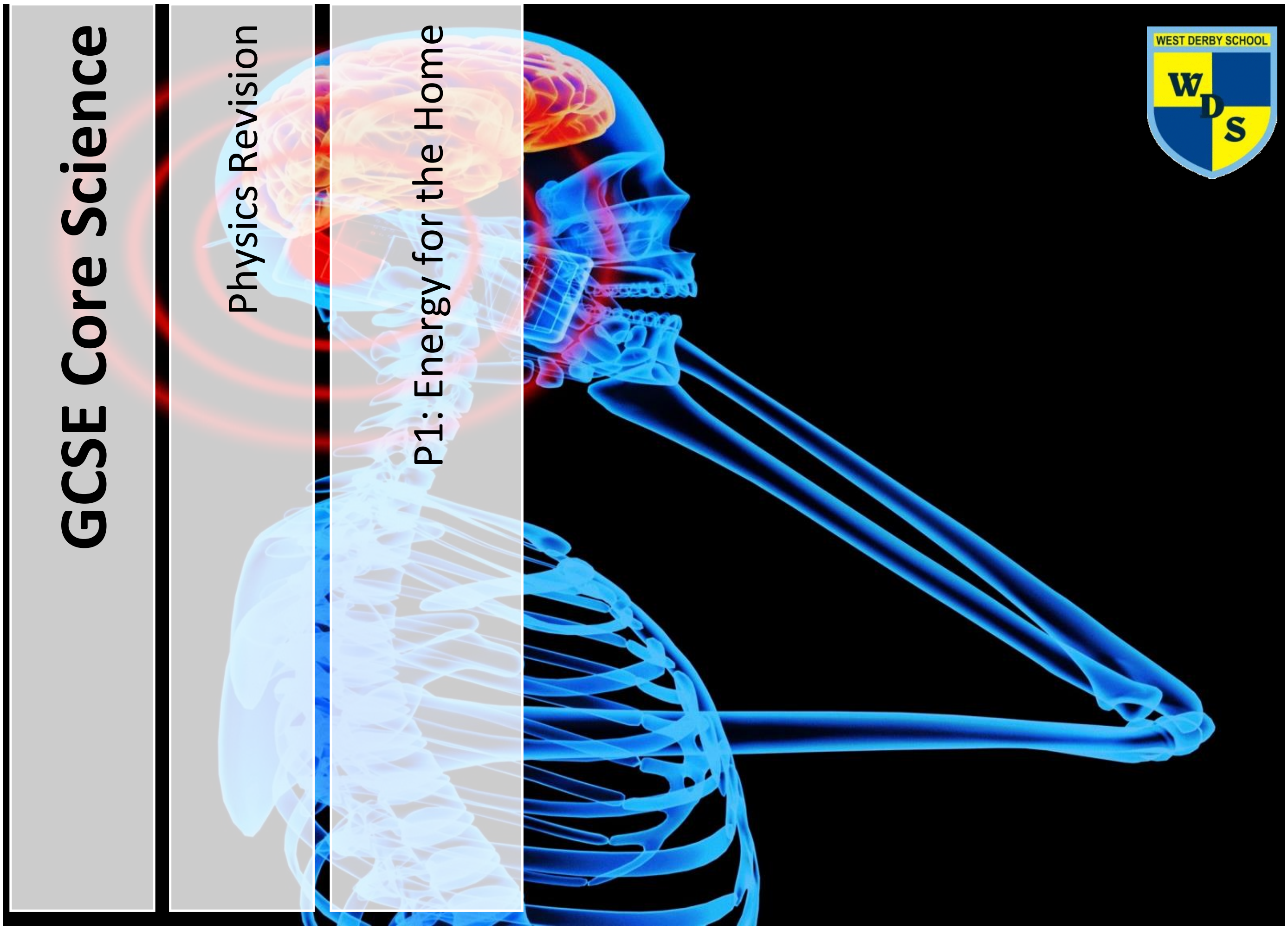


P1: Energy for the Home

1. Heating houses

Heat energy is needed to increase the temperature of an object. The amount of energy needed depends on the mass of the object, the type of material it is made from and the temperature increase.

Heat energy is also absorbed when substances melt or boil, but the temperature does not alter during a change of state. The amount of energy needed to melt or boil something depends upon the mass of the object and the type of material it is made from.

Temperature

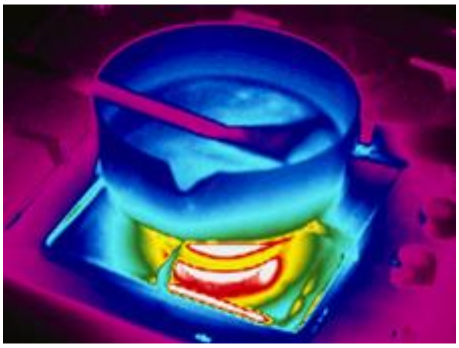
Temperature and **heat** are not the same thing because:

- temperature is a measure of how hot something is
- heat is a measure of the thermal energy contained in an object.

Temperature is measured in ºC, and heat is measured in J.

Thermograms

Thermal imaging cameras can detect infrared radiation - the type of radiation emitted by all objects. The images they produce are called thermograms. False colours are added to a thermogram to give an indication of how hot each object in the image is, with:



Thermogram of a pan being heated on a stove

- the hottest parts are coloured white, yellow or red
- the coldest parts are coloured purple, dark blue or black.

In the thermogram shown here, the burner and its flame are the hottest parts. The pan and its contents are much colder and have yet to warm up.

Changing temperatures

Heat energy flows from a hot object to a cooler one. This causes:

- hot objects to cool down
- cool objects to warm up.

When heat energy is transferred to an object, its temperature increase depends upon:

- the mass of the object
- the substance the object is made from

- the amount energy transferred to the object.

  For a particular object, the more heat energy transferred to it, the greater its temperature increase.

Specific heat capacity

The **specific heat capacity** of a substance is a measure of how much heat energy it can hold. It is the energy needed to increase the temperature of 1 kg of the substance by 1 ºC. Different substances have different specific heat capacities.

Heat capacity of substances

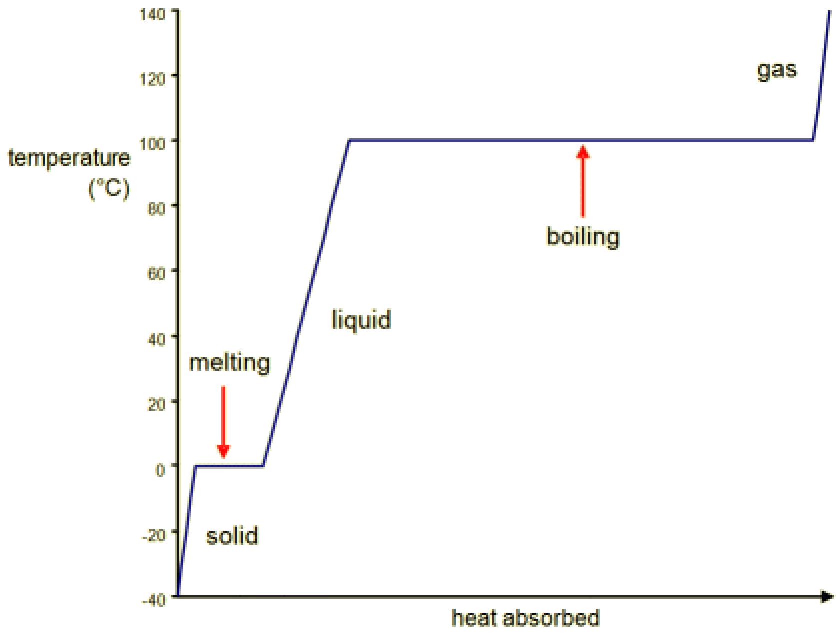
substance	specific heat capacity J/kg/ºC
water	4181
lead	128
oxygen	918

Notice that water has a particularly high specific heat capacity. This makes water useful for storing heat energy, and for transporting it around the home using central heating pipes.

Changing state

A substance must absorb heat energy so that it can melt or boil. The temperature of the substance does not change during melting, boiling or freezing, even though energy is still being transferred.

A heating curve is a graph showing the temperature of a substance plotted against the amount of energy it has absorbed. You may also see a cooling curve, which is obtained when a substance cools down and changes state.



A heating curve for ice

Notice that the temperature stays the same during a change of state, melting or boiling, even though heat energy is still being absorbed.

The temperature also stays the same while a liquid freezes, even though heat energy is still being released to the surroundings.

Specific latent heat

The specific latent heat of a substance is a measure of how much heat energy is needed to melt or boil it. It is the energy needed to melt or boil 1 kg of the substance.

Different substances have different specific latent heats. The specific latent heat of a given substance is different for boiling than it is for melting. The table shows some examples.

Latent heats of substances

substance	specific latent heat of melting kJ/kg	specific latent heat of boiling kJ/kg
water	334	2260
lead	22.4	855
oxygen	13.9	213

Energy calculations

You should be able to state, and use, the equations relating energy to specific heat capacity and to specific latent heat. You may need to rearrange the equations in the exam.

Specific heat capacity

Here is the equation relating energy to specific heat capacity:

energy (J) = mass (kg) × specific heat capacity (J/kg/ºC) × temperature change (ºC)

Question

How much energy is needed to increase the temperature of 500 g of lead from 20 ºC to 45 ºC? The specific heat capacity of lead is 128 J/kg/ºC.

Specific latent heat

Here is the equation relating energy to specific latent heat:

energy (J) = mass (kg) × specific latent heat (J/kg)

Question

How much energy is needed to melt 10 g of ice? The specific latent heat of melting for water is 334,000 J/kg.

Remember that the temperature does not alter during melting and boiling. This is because the energy is used to break the bonds between the particles in the substance.

2. Keeping homes warm

Heat energy can be lost from homes in many different places but there are ways of reducing these losses. Heat can be transferred from place to place by conduction, convection and radiation. Dark matt surfaces are better at absorbing heat energy than light shiny surfaces.

Conduction

Heat is thermal energy. It can be transferred from one place to another by conduction, which involves particles.

Metals are good conductors of heat, but non-metals and gases are usually poor conductors of heat. Poor conductors are called insulators. Heat energy is conducted from the hot end of an object to the cold end.

The electrons in a piece of metal can leave their atoms and move about in the metal as free electrons. The parts of the metal atoms left behind are now charged metal ions. The ions are packed closely together and they vibrate continually. The hotter the metal, the more kinetic energy these vibrations have. This kinetic energy is transferred from hot parts of the metal to cooler parts by the free electrons. These move through the structure of the metal, colliding with ions as they go.

Convection

Heat can be transferred from one place to another by convection. Like conduction, the process involves particles.

Fluids

Liquids and gases are fluids because they can be made to flow. The particles in these fluids can move from place to place. Convection occurs when particles with a lot of heat energy in a liquid or gas move and take the place of particles with less heat energy. Heat energy is transferred from hot places to cooler places by convection.

Liquids and gases expand when they are heated. This is because the particles in liquids and gases move faster when they are heated than they do when they are cold. As a result, the particles take up more volume. This is because the gap between particles widens, while the particles themselves stay the same size.

The liquid or gas in hot areas is less dense than the liquid or gas in cold areas, so it rises into the cold areas. The denser cold liquid or gas falls into the warm areas. In this way, convection currents that transfer heat from place to place are set up.

Heat transfer by radiation

Heat can be transferred by infrared radiation. Unlike conduction and convection, which need particles, infrared radiation is a type of electromagnetic radiation that involves waves.

Light from the sun reaching earth

Radiation can even work through the vacuum of space. This is why we can still feel the heat of the Sun even though it is 150 million km away from the Earth.

Different surfaces

Some surfaces are better than others at reflecting and absorbing infrared radiation. The table summarises some differences.

differences in surfaces absorbing radiation

surface	ability to reflect infrared radiation	ability to absorb infrared radiation
dull or rough	poor	good
shiny	good	poor

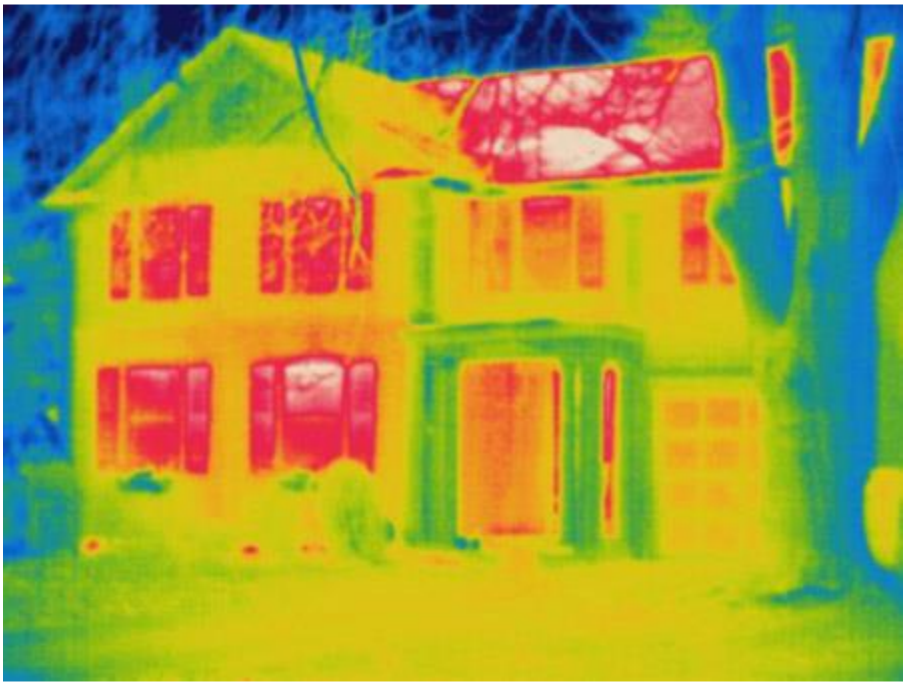
If two objects made from the same material have identical volumes, a thin, flat object will radiate heat energy faster than a fat object. This is one reason why domestic radiators are thin and flat. Radiators are often painted with white gloss paint. They would be better at radiating heat if they were painted with black matt paint, but in fact, despite their name, radiators transfer most of their heat to a room by convection.

Insulating homes

You should be able to describe how heat energy is lost from buildings and to explain how these losses can be reduced.

Heat escape routes

Take a look at this thermogram of a house. The roof and windows are the hottest, showing that most heat is lost from the house that way.



Most household heat is lost through the windows and roof

Heat energy is transferred from homes by conduction through the walls, floor, roof and windows. It is also transferred from homes by convection. For example, cold air can enter the house through gaps in doors and windows, and convection currents can transfer heat energy in the loft to the roof tiles. Heat energy also leaves the house by radiation through the walls, roof and windows.

Ways to reduce heat loss

There are some simple ways to reduce heat loss, including fitting carpets, curtains and draught excluders. It is even possible to fit reflective foil in the walls or on them.

Heat loss through windows can be reduced by using double glazing. These special windows have air or a vacuum between two panes of glass. Air is a poor conductor of heat, while a vacuum can only transfer heat energy by radiation.

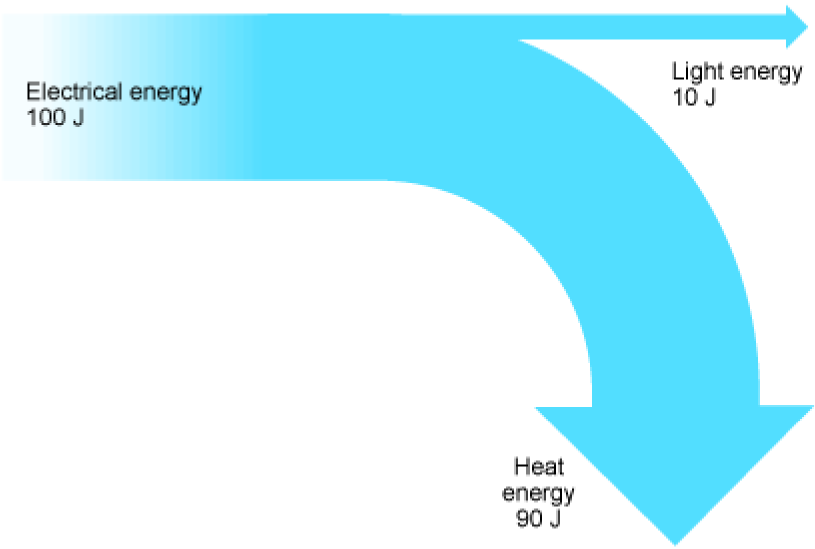
Heat loss through walls can be reduced using cavity wall insulation. This involves blowing insulating material into the gap between the brick and the inside wall, which reduces the heat loss by conduction. The material also prevents air circulating inside the cavity, therefore reducing heat loss by convection.

Heat loss through the roof can be reduced by laying loft insulation. This works in a similar way to cavity wall insulation.

Sankey diagrams

Sankey diagrams summarise all the energy transfers taking place in a process. The thicker the line or arrow, the greater the amount of energy involved.

The Sankey diagram for an electric lamp below shows that most of the electrical energy is transferred as heat rather than light.



Sankey diagram for a filament lamp

Energy can be **transferred** usefully, stored or dissipated. **It cannot be created or destroyed**. Notice that 100 J of electrical energy is supplied to the lamp. Of this, 10 J is transferred to the surroundings as light energy. The remainder, 90 J (100 J – 10 J) is transferred to the surroundings as heat energy.

The energy transfer to light energy is the useful transfer. The rest is **'wasted'** - it is eventually transferred to the surroundings, making them warmer. This 'wasted' energy eventually becomes so spread out that it becomes less useful.

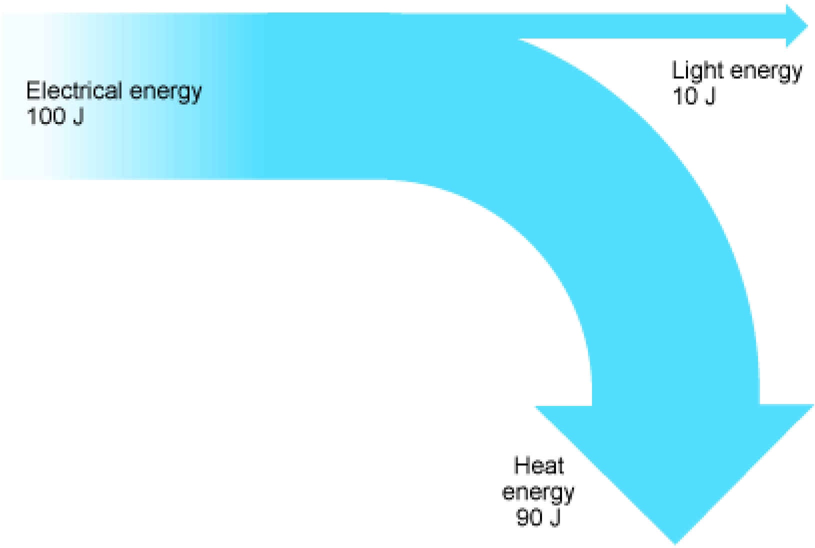
Efficiency and payback time

Efficiency

The efficiency of a device is the proportion of the energy supplied that is transferred in useful ways. You should be able to calculate the efficiency of a device as a decimal or as a percentage.

The efficiency of a device can be calculated:

- efficiency = useful energy out ÷ total energy in (for a decimal efficiency)
- efficiency = (useful energy out ÷ total energy in) × 100 (for a percentage efficiency)



Sankey diagram for a filament lamp

The efficiency of the filament lamp is 10 ÷ 100 = 0.10 (or 10 per cent)

This means that only 10 per cent of the electrical energy supplied is transferred as light energy (90 per cent is transferred as heat or 'wasted' energy).

Note that the efficiency of a device will always be less than 1.

Payback time

Home owners may install double glazing or extra insulation to reduce heat energy losses and so save money. However, these energy-saving solutions cost money to buy and install. The payback time of an energy-saving solution is a measure of how cost-effective it is. Here is the equation to calculate payback time:

payback time (years) = cost of installation (£) ÷ savings per year in fuel costs (£)

The payback time will be shortest if the cost of installation is low compared to the savings made each year.

3. An introduction to waves

Light can be used for digital communications - for example, in Morse code and in CD players. Light consists of transverse waves in which the electromagnetic vibrations are at 90º to the direction of travel. The speed of a wave can be calculated using its frequency and wavelength. Lasers produce intense narrow beams of light.

Transverse waves

Waves are vibrations that transfer energy from place to place without matter - solid, liquid or gas - being transferred. Think of a Mexican wave in a football crowd. The wave moves around the stadium, while each spectator stays in their seat - only moving up, and then down, when it is their turn.

In transverse waves, the oscillations (vibrations) are at right angles to the direction of travel and energy transfer. Water waves are transverse waves.

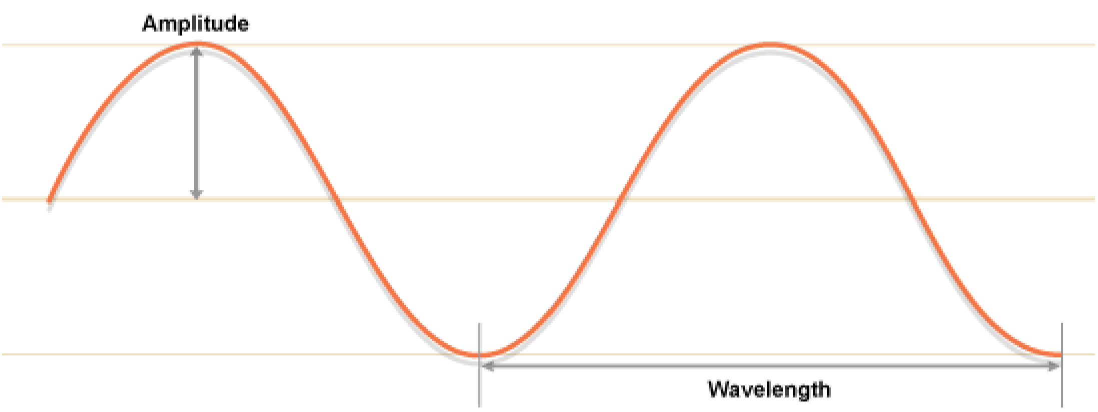
Light and other types of electromagnetic radiation are transverse waves. All types of electromagnetic waves travel at the same speed through a vacuum, such as through space

Features of waves

You should understand what is meant by the amplitude, wavelength and frequency of a wave.

Amplitude

As waves travel, they set up patterns of disturbance. The amplitude of a wave is its maximum disturbance from its undisturbed position. Take care: the amplitude is not the distance between the top and bottom of a wave.



Amplitude and wavelength

Wavelength

The wavelength of a wave is the distance between a point on one wave and the same point on the next wave. It is often easiest to measure this from the crest of one wave to the crest of the next wave, but it doesn't matter where as long as it is the same point in each wave.

Frequency

The frequency of a wave is the number of waves produced by a source each second. It is also the number of waves that pass a certain point each second. The unit of frequency is the hertz (Hz), which is one wave per second.

It is common for kilohertz (kHz), megahertz (MHz) and gigahertz (GHz) to be used when waves have very high frequencies. For example, most people cannot hear a high-pitched sound above 20 kHz, radio stations broadcast radio waves with frequencies of about 100 MHz, while most wireless computer networks operate at 2.4GHz.

Wave speed

You should know and be able to use the relationship between wave speed, frequency and wavelength.

How fast do waves travel?

The speed of a wave - its wave speed - is related to its frequency and wavelength, according to this equation:

wave speed (m/s) **= frequency** (hertz, Hz) **× wavelength** (metre, m)

All waves obey this wave equation. For example, a wave with a frequency of 100 Hz and a wavelength of 2m travels at 100 × 2 = 200 m/s.

Reflection

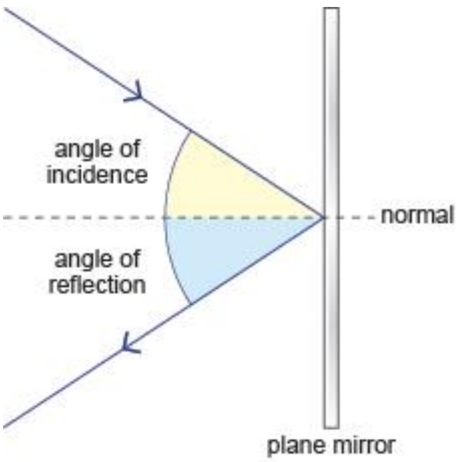
Light waves reflect from surfaces. When waves reflect, they obey the law of reflection: the angle of incidence equals the angle of reflection.

- The normal is a line drawn at right angles to the reflector.
- The angle of incidence is between the incident (incoming) ray and the normal.
- The angle of reflection is between the reflected ray and the normal.

Smooth surfaces produce strong echoes when sound waves hit them, and they can act as mirrors when light waves hit them. The waves are reflected uniformly and light can form images. In the plane (flat) mirror, the image appears to be behind the mirror.

Constructing a ray diagram

In a ray diagram, the mirror is drawn a straight line with thick hatchings to show which side has the reflective coating. The light rays are drawn as solid straight lines, each with an arrowhead to show the direction of travel.



A ray diagram

Refraction

Light waves change speed when they pass across the boundary between two substances with different densities, such as air and glass. This causes them to change direction and this effect is called refraction.

There is one special case you need to know. Refraction doesn't happen if they cross the boundary at an angle of 90° (called the normal) - in that case they carry straight on.

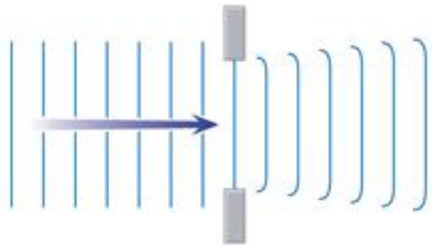
The refraction follows a regular pattern.

Diffraction

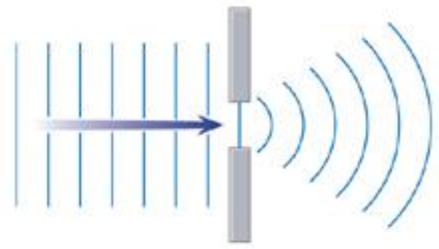
When waves meet a gap in a barrier, they carry on through the gap. However, the waves spread out to some extent into the area beyond the gap. This is diffraction.

The extent of the spreading depends on how the width of the gap compares to the wavelength of the waves. Significant diffraction only happens when the wavelength is of the same order of magnitude as the gap. For example:

- a gap much larger than the wavelength causes little spreading and a sharp shadow eg light through a doorway
- a gap similar to the wavelength causes a lot of spreading with no sharp shadow eg sound through a doorway



Diffraction through a wide gap



Diffraction through a narrow gap

Diffraction - Higher tier

Diffraction reduces the quality of images seen in microscopes and telescopes. It can cause rings or spikes around the image of the object being viewed.

4. A spectrum of waves

White light can be split up into many colours by using a prism. This visible light is just part of the whole spectrum of electromagnetic radiation. Not all types of electromagnetic radiation are visible. Each type has a different wavelength and a different use in everyday life. Electromagnetic radiation can be used for wireless communications.

The electromagnetic spectrum

White light can be split up using a prism to form a spectrum. A prism is a block of glass with a triangular cross-section. The light waves are refracted as they enter and leave the prism. The shorter the wavelength of the light, the more it is refracted. As a result, red light is refracted the least and violet light is refracted the most, causing the coloured light to spread out to form a spectrum.

Refraction from a prism

Visible light is just one type of electromagnetic radiation. There are various types of electromagnetic radiation, some with longer wavelengths than visible light and some with shorter wavelengths than visible light.

The electromagnetic spectrum

Electromagnetic waves form a continuous spectrum. You should know the order of electromagnetic waves in the spectrum (see below).

Electromagnetic waves in the spectrum

Energy	Frequency	Wavelength	Type of electromagnetic radiation	Uses
Lowest	Lowest	Longest	Radio waves	Television signals
			Microwaves	Cooking, mobile phones
			Infrared	Optical fibre communication

Energy	Frequency	Wavelength	Type of electromagnetic radiation	Uses
			Visible light	Seeing
			Ultraviolet	Detecting forged bank notes
			X-rays	Medical images of bones
Highest	Highest	Shortest	Gamma radiation	Killing cancer cells

Communicating with waves

Electromagnetic radiation can be used for wireless communications.

Radio waves

Radio waves are used to transmit television and radio programmes. Television uses higher frequencies than radio.

Microwaves

Microwave radiation can be used to transmit signals such as mobile phone calls.

Infrared

Infrared radiation is used to transmit information from place to place, including:

- remote controls for television sets and DVD players
- data links between computers.

Optical fibres

Visible light

Visible light is the light we can see. It allows us to communicate with one another through books, hand signals and video, for example. The use of visible light needs the transmitter and receiver to be in the line of sight. But it is more secure against eavesdroppers than radio waves.

5. Light and lasers

Digital signals are a series of pulses with two states - on or off. Light can be used for digital communications, such as in Morse code and CD players. Optical fibres can carry information coded in light waves or infrared waves. Lasers produce intense narrow beams of light.

Morse code

Morse code was invented by Samuel Morse in 1832. Letters and numbers are represented by a series of dots and dashes - a dash lasts three times longer than a dot.

A •—	J •———	S •••	1 •————
B —•••	K —•—	T —	2 ••———
C —•—•	L •—••	U ••—	3 •••——
D —••	M ——	V •••—	4 ••••—
E •	N —•	W •——	5 •••••
F ••—•	O ———	X —••—	6 —••••
G ——•	P •——•	Y —•——	7 ——•••
H ••••	Q ——•—	Z ——••	8 ———••
I ••	R •—•	0 —————	9 ————•

The Morse code

Morse code is a digital signal. It can be transmitted in many different ways, including visible light, radio waves and electrical pulses.

Sending information using electrical pulses requires wires, unlike visible light and radio waves, which are wireless. The use of visible light needs the transmitter and receiver to be in the line of sight, but that is more secure against eavesdroppers than radio waves.

Total internal reflection

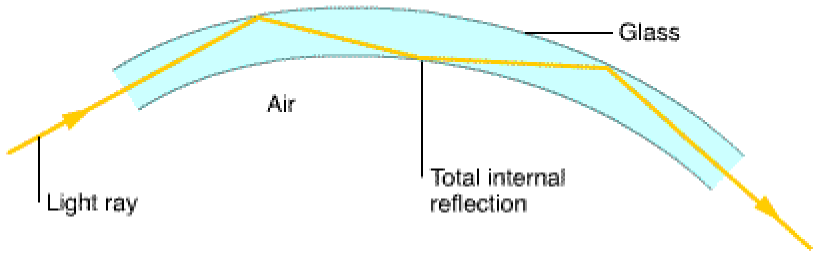
Light rays and infrared rays change speed when they pass from glass to air, or Perspex to air. This is because air and glass - or Perspex - have different densities. The rays change direction if they hit the boundary of the material at an angle other than 90°. Beyond a certain angle, called the critical angle, all the rays reflect back into the glass or Perspex. This is called total internal reflection, TIR.

Have a go at the animation to check your understanding of this.

All light rays that hit the surface beyond the critical angle are effectively trapped. The critical angle for glass is about 42°.

Optical fibres

An optical fibre is **a thin rod of high-quality glass**. Very little light is absorbed by the glass. Light getting in at one end undergoes repeated total internal reflection, even when the fibre is bent, and emerges at the other end.



Optical fibre

Information such as computer data and telephone calls can be **converted into electrical signals**. These can be carried through cables, or transmitted as microwaves or radio waves. However, the information can also be converted into either visible light signals or infrared signals, and transmitted by optical fibres.

Optical fibres

Optical fibres are also used in endoscopes that allow surgeons to see inside their patients.

Lasers

A laser - 'Light Amplification by Stimulated Emission of Radiation' - produces an intense narrow beam of light. The light from a laser is monochromatic (a single colour).

Some lasers are capable of heating materials. This makes them useful in surgery and for cutting metals and other industrial materials.

A typical laser beam might only spread out by 1 m when shone onto a surface 1 km away. As light also travels in straight lines, this makes lasers useful for guiding weapons to their targets, and for laser light shows.

Lasers - Higher tier

The light waves have a low divergence (they spread out very little). They are coherent, which means that they are:

- the same frequency
- in phase with each other.

When light waves are in the same phase, their crests all line up, as do their troughs.

Laser beams are used to read information from CDs in CD players. The shiny surface of a CD contains billions of microscopic pits in a spiral track. The pattern of pits contains digital information. The laser light is reflected off the surface of the CD as the disk spins, and is detected by:

- the change in the amount of reflected light caused by entering or leaving a pit is interpreted as a 1
- no change in the amount of reflected light is interpreted as a 0.

6. Cooking and communication using waves

Infrared radiation and microwaves can be used to cook food. Microwaves are also used to transmit information, such as mobile phone networks.

Cooking with infrared

All objects give out and take in infrared radiation. The hotter an object is, the more infrared radiation it emits.

Very hot objects may glow, such as the heating element in a toaster or an electric fire. Other hot objects may not glow, such as an iron.

Some surfaces are better than others at emitting and absorbing infrared radiation:

surfaces that emit and absorb radiation

colour	texture	ability to emit infrared radiation	ability to absorb infrared radiation
black	dull	good	good
white	shiny	poor	poor

Shiny surfaces reflect infrared radiation.

When an object absorbs infrared radiation, its temperature increases. Food, for instance, begins to cook when its surface absorbs infrared radiation.

Cooking with microwaves

Microwave radiation has lower frequencies and longer wavelengths than visible light. Microwaves cannot be seen, but they can cause burns if they are absorbed by body tissues. Microwave ovens rely on the ability of microwaves to penetrate about 1 cm into food. They are absorbed by water in the food, causing it to warm up.

Microwaves pass through plastics and glass, but are reflected by metals. The water in living cells can also absorb microwave radiation. As a result, they can be killed or damaged by the heat released.

To protect us from the harmful effects of microwaves, microwave ovens have metal cases and the glass doors have a metal mesh.

There is a British Standard which sets a safe limit of 50 watts per square metre at 5 cm. This means that measurements of microwave power taken at 5 cm from the microwave must be less than 50 watts per square metre.

Communicating with microwaves

Mobile phones communicate with their base stations using low-intensity microwave radiation. Microwaves can be used to transmit information over large distances, although some areas have poor signals. The use of mobile phones means people are exposed to microwave radiation in two ways:

- to the head from the aerial in the phone
- to the body from transmitters in base station masts.

Mobile phone use

Microwaves from the phone can penetrate body tissues to a depth of a few centimetres. They are absorbed, and give up their energy to body tissues. This can cause a small amount of heating, about 0.1°C. This is much less than if you stand in sunshine.

There have been several studies into the possible health effects of mobile phones and masts. However, there is no conclusive evidence that they can damage your health, or indeed that they cannot. But because millions of people use mobiles, many authorities believe it is sensible to advise the public to take precautions, just in case. In particular, there are concerns about children using mobile phones, and about people using them very often.

There are limits to the amount of microwave radiation that can be emitted by mobile phones. This Specific Absorption Rate - SAR - should not be more than 2 watts per kilogram.

Microwaves - Higher tier

Transferring energy

You should be able to explain how infrared radiation and microwaves transfer energy to materials such as food.

In each case, the kinetic energy of particles is increased when the radiation is absorbed:

- infrared radiation is absorbed by all particles on the surface

- microwave radiation is absorbed by water particles, both on the surface and up to about 1 cm deep into the food.

The kinetic energy is transferred to the centre of the food by conduction or convection.

Potential dangers

The higher the frequency of an electromagnetic wave, the greater the energy it transfers for a given amplitude. Infrared radiation has a higher frequency than microwaves. It can transfer enough energy to break chemical bonds. Microwaves cannot.

Siting mobile phone transmitters

Mobile phone base station

Microwave transmitters and receivers must be in line of sight. There are also other factors that limit how far apart transmitters can be.

- There is no diffraction of microwaves around large buildings, so microwaves may be blocked by large buildings and other obstacles.
- Poor weather and surface water scatter signals.
- Signals may interfere with each other.

Transmitters are usually placed high up, on masts. Home wireless networks, for example, often work better if the wireless router is placed in the loft.

7. Data transmission

Information can be transmitted using analogue or digital signals.

Analogue and digital signals

Communications signals can be analogue or digital.

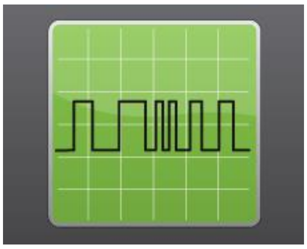
Analogue signals

Music and speech vary continuously in frequency and amplitude. In the same way, analogue signals can vary in frequency, amplitude, or both. You may have heard of FM and AM radio - Frequency Modulated radio and Amplitude Modulated radio. The diagram shows a typical oscilloscope trace of an analogue signal.

Oscilloscope trace of an analogue signal

Digital signals

Digital signals are a series of pulses consisting of just two states: ON (1) or OFF (0). There are no values in between. DAB radio is Digital Audio Broadcast radio - it is transmitted as digital signals. The diagram shows a typical oscilloscope trace of a digital signal.



Oscilloscope trace of a digital signal

Noise

You should be able to explain why digital signals maintain their quality better than analogue signals.

Noise

All signals become weaker as they travel long distances, and they may also pick up random extra signals. This is called noise, and it is heard as crackles and hiss on radio programmes. Noise may also cause an internet connection to drop or slow down, as the modem tries to compensate.

Analogue signals

Noise adds extra random information to analogue signals. Each time the signal is amplified, the noise is also amplified. Gradually, the signal becomes less and less like the original signal. Eventually, it may be impossible to make out the music in a radio broadcast against the background noise, for example.

Digital signals

Noise also adds extra random information to digital signals. However, this noise is usually lower in amplitude than the amplitude of the ON states. As a result, the electronics in the amplifiers can ignore the noise and it does not get passed along. This means that the quality of the signal is maintained, which is one reason why television and radio broadcasters are gradually changing from analogue to digital transmissions.

Data transmission

We cannot see infrared radiation, but we can feel it as heat energy. Infrared sensors can detect heat from the body. They are used in:

- security lights
- burglar alarms.

Infrared radiation is also used to transmit information from place to place, including:

- remote controls for television sets and DVD player
- data links over short distances between computers or mobile phones.

Optical fibres

Information such as computer data and telephone calls can be converted into electrical signals. These can be carried through cables, or transmitted as microwaves or radio waves. However, the information can also be converted into pulses of infrared radiation and transmitted by optical fibres.

Optical fibres can carry more information than an ordinary cable of the same thickness. The signals in optical fibres do not weaken as much over long distances as the signals in ordinary cables.

Higher tier

Optical fibres can carry more data because of multiplexing. This is where several digital signals are interleaved or carried together without being mixed. Digital radio and TV broadcasts also carry more data than analogue broadcasts: they can also be multiplexed. This allows for a more efficient use of the available radio frequencies, for example to carry many more channels or to allow high-definition (HD) television and ‘red button’ options.

8. Wireless signals

Wireless communication is convenient. It is used for radio programmes, mobile phones and computer networks. DAB broadcasts have advantages and disadvantages compared to traditional analogue broadcasts.

Uses of wireless technology

Electromagnetic radiation can be used for wireless communications. For example:

- radio waves are used to transmit television and radio programmes
- microwaves are used to transmit mobile phone calls.

Radio stations with similar transmission frequencies can interfere with each other's signals.

Microwaves are also used to network computers together, especially laptop computers.

Wireless communications can be available all of the time, almost anywhere. They have several advantages over wired communications. These include:

- no wires need to be run through buildings, over ground or underground
- wireless devices can be portable.

An aerial is needed to pick up the signals but these are much smaller in equipment today than in the past. They are not even visible in modern mobile phones and laptop computers.

DAB and FM broadcasts

Radio stations whose transmitters are near each other need to broadcast on different frequencies to avoid interference between the signals.

DAB - Digital Audio Broadcasting - is a digital system for transmitting radio programmes. FM, Frequency Modulation, is an analogue system for transmitting radio programmes. Both have advantages and disadvantages. For example:

DAB makes more radio stations available and suffers from less interference from other broadcasts. On the other hand, DAB may have a poorer audio quality than FM, and not all areas of the UK are currently covered by DAB broadcasts.

Effects of refraction and reflection

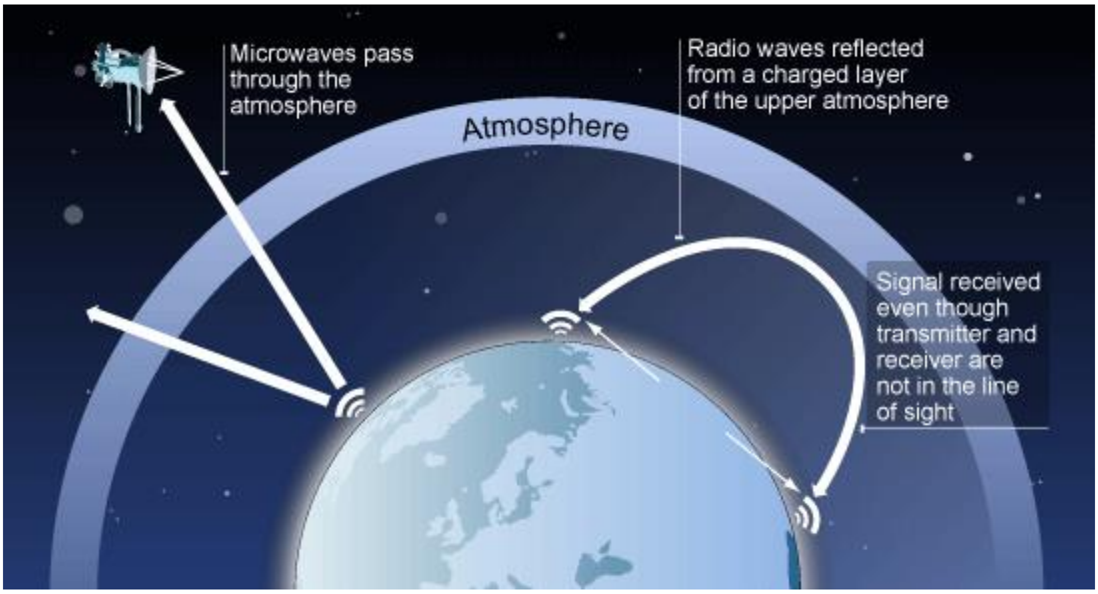
Reflection and refraction are important in communications signals.

Reflection

Wireless signals can be reflected off buildings and other large objects. This means that signals may be received even if the receiver is not in direct sight of the transmitter. But it can also cause 'ghosting' on television pictures, for example.

Refraction

Radio waves are refracted by different layers in the Earth's atmosphere. This leads to a reduction in the signal, making it difficult for them to be received over long distances. Unlike radio waves, microwaves are not refracted, so they are used for satellite communications.



Microwaves and radio waves in the atmosphere

Signals can be received by satellites and then re-transmitted back to Earth.

9. Stable Earth

Earthquakes produce shock waves that cause damage. There are two types of seismic wave, P-waves and S-waves. Seismometers can detect these waves and provide evidence of the Earth's structure.

The ozone layer reduces the amount of ultraviolet light from the Sun that reaches the Earth's surface. Exposure to ultraviolet radiation can lead to sunburn and skin cancer, but sunscreens can reduce this damage.

Earthquakes

The Earth's crust and upper mantle are broken up into huge **tectonic plates**. Where these meet, the Earth's crust becomes unstable and earthquakes and volcanic eruptions occur.

Earthquakes cause damage to buildings and often lead to loss of life. It is difficult to predict exactly when an earthquake might happen and how bad it will be, even in places that are known for having earthquakes.

Seismic waves

Earthquakes produce shock waves. These travel through the Earth and can be detected using a device called a **seismometer**.

There are two types of seismic wave, as described in the table below:

Properties of seismic waves

	P-waves	S-waves
type of wave	longitudinal	transverse
relative speed	fast	slow
can travel through	solids and liquids	solids only

P-waves are longitudinal waves like sound waves, and S-waves are transverse waves like light waves.

Remember: S (wave) … Side to side, Slow, Solids.

Ultraviolet radiation

Ultraviolet radiation is found naturally in sunlight. Exposure to ultraviolet radiation can cause our skin to tan. It can also cause:

- sunburn
- skin cancer
- eye cataracts
- premature ageing of the skin.

There is a public health issue about ultraviolet radiation from the Sun and sunbeds. Health education programs aim to inform people about the dangers of ultraviolet radiation.

Umbrellas can be useful in the sun as well as the rain

We cannot see or feel ultraviolet radiation, but our skin responds to it by turning darker. This happens in an attempt to reduce the amount of ultraviolet radiation that reaches deeper skin tissues.

Darker skins absorb more ultraviolet light, so less ultraviolet radiation reaches the deeper tissues. This is important because ultraviolet radiation can cause normal cells to become cancerous.

Sunscreens

Sunscreens can reduce the damage caused by ultraviolet radiation. They contain chemicals that absorb a lot of the radiation and prevent it from reaching our skin. They may also contain chemicals that reflect some of the radiation away from the skin.

Manufacturers of sunscreens make products with different sun protection factors, SPFs:

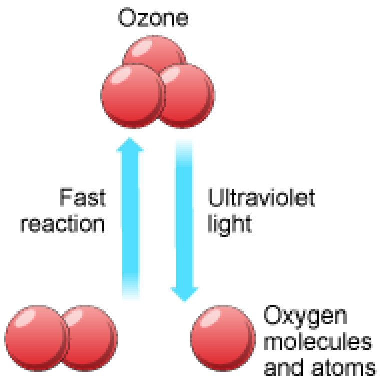
- the higher the factor, the longer you can stay out in the sun without burning
- high factor sunscreens reduce the risks from ultraviolet radiation more than low factor sunscreens.

If, for example, you would get sunburnt after ten minutes in the sun, with Factor 5 applied you could stay in the sun for 50 minutes - or for 500 minutes with Factor 50 applied. But the real time is usually lower, because some of the sunblock gets absorbed by the skin, and some gets rubbed off.

The ozone layer

Ozone

Ozone O_3 is an ‘allotrope’ of oxygen - a form of oxygen that is different to O_2, the gas that makes up 21 per cent of the atmosphere. Ozone is formed from oxygen in a reversible reaction.



Ozone molecule formation

The ozone layer

The ozone layer is the part of the upper atmosphere where ozone is found in the highest concentrations. The ozone there absorbs ultraviolet radiation, preventing most of it from reaching the ground. This is important because ultraviolet radiation can lead to skin cancer.

Near the end of the last century, scientists discovered that ozone levels over the Antarctic were reduced. This discovery was unexpected. Chemists knew that reactive chlorine atoms could destroy ozone. They also knew that chemicals called chlorofluorocarbons - CFCs - break down in ultraviolet light to release reactive chlorine atoms. Scientists used these ideas to explain the low ozone levels.

CFCs were once used widely in insulating foam and aerosol spray-cans. Once released, they gradually spread through the atmosphere, eventually reaching the ozone layer. Once there, they destroy ozone. CFCs have now been almost completely replaced by chemicals that do not cause this damage.

Seismic waves - Higher tier

Knowledge of how seismic waves travel through the Earth provides us with evidence of the Earth's structure. Remember that:

- P-waves travel through solids and liquids, so they can travel through all of the Earth's layers
- S-waves cannot travel through liquid rock, so they cannot travel through the outer core

The speed of P-waves and S-waves increases as they travel deeper into the mantle. They travel through the Earth in curved paths, but they change direction suddenly when they pass through the boundary between substances in different states. The diagrams show what happens when P-waves and S-waves pass through the Earth.

S-waves

S-waves travel through solids only. They cannot travel through the liquid outer core, but they can travel through the mantle and crust.

P-waves

Unlike S-waves, P-waves can pass through the liquid outer core. When P-waves pass from solid to liquid, then from liquid to solid, there are sudden changes in direction. The waves are refracted.