

# AQA GCSE Physics

## Topic 6: Waves

### Notes

(Content in bold is for Higher Tier only)



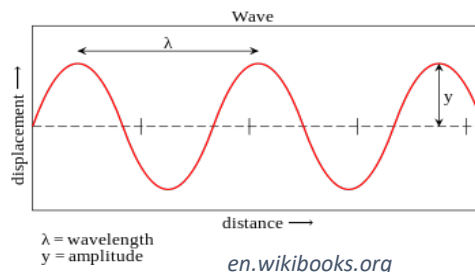
## Waves

- Wavelength – distance between the same points on two consecutive waves,  
 Amplitude – distance from equilibrium line to the maximum displacement (crest or trough)  
 Frequency – the number of waves that pass a single point per second  
 Period – the time taken for a whole wave to completely pass a single point

$$\text{velocity} = \text{frequency} \times \text{wavelength} = v = f\lambda$$

$$\text{period} = \frac{1}{\text{frequency}} = T = \frac{1}{f}$$

Where the period, T in seconds s and the frequency, f in hertz Hz.



## Relationships (physics only)

- Increase frequency, velocity increases
- Wavelength increases, velocity increases
- Period is inversely proportional to frequency
- Smaller period, higher frequency, greater velocity

## Types of Waves

- **Transverse** waves
  - o Eg/ Light, or any electromagnetic wave
  - o Have peaks and troughs
  - o Vibrations are at right angles to the direction of travel
- **Longitudinal** waves
  - o Eg/ Sound waves
  - o Have compressions and rarefactions
  - o Vibrations are in the same direction as the direction of travel
- Remember, for both types, the wave moves and not whatever it passes through
  - o I.e. a water wave has a moving wave, but the water doesn't keep moving with it

## Measuring velocity

- Sound in air
  - o Make a noise at ~50m from a solid wall, and record time for the echo to be heard, then use speed = distance/time
  - o Have two microphones connected to a datalogger at a large distance apart, and record the time difference between a sound passing one to the other – then use speed = distance/time
- Ripples on water surface
  - o Use a **stroboscope**, which has the same frequency as the water waves, then measure distance between the 'fixed' ripples and use

$$v = f\lambda$$

Where v is the wave speed in metres per second m/s, f is the frequency in hertz Hz and  $\lambda$  is the wavelength in metres m.

- o Move a pencil along the paper at the same speed as a wavefront, and measure the time taken to draw this line – then use speed = distance/time

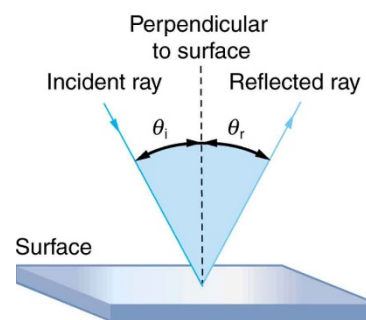


## Interactions (Physics only)

Waves can be reflected, absorbed, or transmitted at the boundary between two different materials.

### Reflection (Physics only)

- Waves will reflect off a flat surface
- The smoother the surface, the stronger the reflected wave is
- Rough surfaces scatter the light in all directions, so they appear matt and not reflective.
- The angle of incidence = angle of reflection
- Light will reflect if the object is opaque and is not absorbed by the material
  - o The electrons will absorb the light energy, then reemit it as a reflected wave



### Transmission (Physics only)

- Waves will pass through a transparent material
- The more transparent, the more light will pass through the material
- It can still refract, but the process of passing through the material and still emerging is transmission

### Absorption (Physics only)

- If the frequency of light matches the energy levels of the electrons
- The light will be absorbed by the electrons and not reemitted
- They will be absorbed, and then reemitted over time as heat
- So that particular frequency has been absorbed
- If a material appears green, only green light has been reflected, and the rest of the frequencies in visible light have been absorbed

## Sound Waves (Physics only)

- **Sound waves can travel through solids causing vibrations in the solid.**
- **The outer ear collects the sound and channels it down the ear canal.**
- **As it travels down, it still is a pressure air wave**
- **The sound waves hit the eardrum**
  - o **Tightly stretched membrane which vibrates as the incoming pressure waves reach it**
    - **Compression forces the eardrum inward**
    - **Rarefaction forces the eardrum outward, due to pressure**
  - o **The eardrum vibrates at the same frequency as the sound wave**
  - o **The small bones connected to this also vibrate at the same frequency (stirrup bone)**
- **Vibrations of the bones transmitted to the fluid in the inner ear**
- **Compression waves are thus transferred to the fluid (in the cochlea)**
  - o **The small bones act as an amplifier of the sound waves the eardrum receives**
  - o **As the fluid moves due to the compression waves, the small hairs that line the cochlea move too**
  - o **Each hair is sensitive to different sound frequencies, so some move more than others for certain frequencies**
    - **The hairs each come from a nerve cell**



- when a certain frequency is received, the hair attuned to that specific frequency moves a lot, releasing an electrical impulse to the brain, which interprets this to a sound

### Limitations (Physics only)

- Humans cannot hear below 20Hz or above 20kHz
- In the cochlea, the hairs attuned to the higher frequencies die or get damaged
  - Can be due to constant loud noise damaging these hairs over the years
  - Or can be due to the changes in the inner ear as you grow older
  - Smoking, chemotherapy, diabetes are also all causes
  - So higher frequencies cannot be heard as we get older
- We have evolved to hear this range of frequencies as it gives us the greatest survival advantage
  - We cannot hear ultrasound as we do not use sonar to hunt etc. we have accurate vision instead

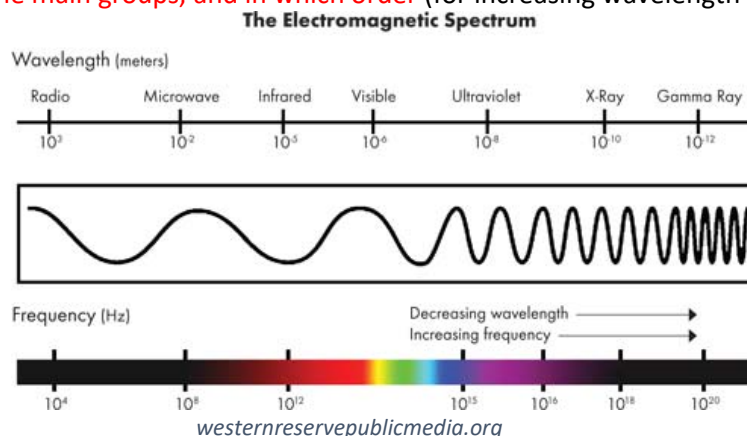
### Ultrasound (Physics only)

- When ultrasound reaches a boundary between two media, they are partially reflected back
- The remainder of the waves continue and pass through
- So a receiver next to the emitter can record the reflected waves
  - The speed of the waves are constant, so measuring the time between emission and detection can show distance from the source they are
  - Or can be used for imaging under surfaces
    - A crack in a metal block will cause some waves to reflect earlier than the rest, so will show up
    - Scan of human foetus also use ultrasound for their non-invasive imaging
- Infrasound is the opposite of ultrasound – it is a sound wave with a frequency lower than 20Hz – also known as seismic waves. There are two: P and S waves
  - This is used to explore the Earth's core
  - P waves are longitudinal, and can pass through solids and liquids
  - S waves are transverse, only passing through solids (these move slower too)
  - On the opposite side of the Earth to an earthquake, only P waves are detected, suggesting the core of the Earth is liquid – hence no S waves can penetrate it
- Sonar
  - Pulse of ultrasound is sent below a ship, and the time taken for it to reflect and reach the ship can be used to calculate the depth
  - This is used to work out whether there is a shoal of fish below the ship
  - Or how far the seabed is below the ship



## Electromagnetic Waves

**Need to learn the main groups, and in which order** (for increasing wavelength or frequency)



- These are transverse waves
- Do not need particles to move
- In space, all waves have the same velocity (speed of light)
- They can transfer energy from a source to absorber
  - o Microwave source to food
  - o Sun emits energy to Earth

### Relationships

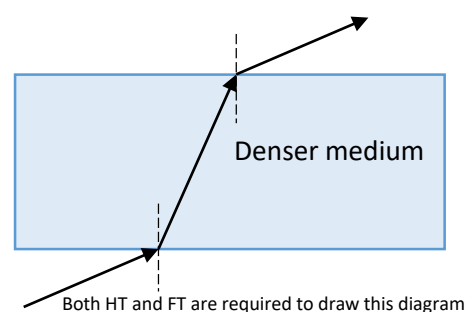
- **As speed is constant for all EM waves**
- **As wavelength decreases, frequency must increase**
- **As frequency increases, energy of the wave increases**

### Eyes

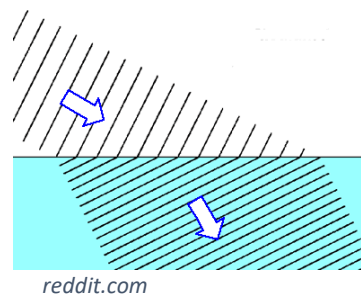
- Our retina can only detect visible light, a small part of the entire EM spectrum
- This visible light is still an EM wave like X rays and microwaves, do not forget!

### Refraction

- If entering a **denser material, it bends towards the normal**
- If entering a less dense material, it bends away from normal
- **Substances will absorb, transmit, refract or reflect certain EM waves depending on wavelength**
  - o E.g. Glass, will transmit/refract visible light
  - o Absorb UV radiation
  - o Reflect IR radiation
  - o The material interacts differently for different parts of EM spectrum because the wavelengths (and frequencies) are different
- **Some effects are due to differences in velocity**
  - o When light enters a denser medium, it slows down
  - o Shorter wavelengths slow down more than longer wavelengths
    - E.g. Blue light slows down more than red



- **Why does dispersion occurs of white light into a prism?**
  - **The different wavelengths refract a different amount, and therefore spread out creating a rainbow effect**
- **When refracting, the speed decreases and wavelength decreases too in denser material, the horizontal lines show the “wave-fronts” of the waves (imagine each line is each maxima of the transverse wave)**



### Radio Waves

- **Radio waves are produced by oscillations in electrical circuits**
- **When radio waves are absorbed they create an alternating current, AC, at the same frequency as the radio waves**

### Atoms and EM Radiation

- When electrons change orbit (move closer or further from the nucleus)
  - o When electrons move to a higher orbit (further from the nucleus)
    - The atom has absorbed EM radiation
  - o When the electrons falls to a lower orbit (closer to the nucleus)
    - The atoms has emitted EM radiation
- If an electron gains enough energy, it can leave the atom to form an ion
- So gamma rays originate from changes in the nucleus of an atom

### Hazards

- UV light, X-rays and gamma can have hazardous effects on human body tissue.
- The effects depend on the type of radiation and the size of the dose
- Radiation dose: how much exposure leads to harm for a person
  - o UV – skin ages prematurely, increasing risk of skin cancer
    - Sun cream prevents over-exposure in summer
  - o X-ray and gamma are ionisation radiation that can cause the mutation of genes – causing cancer
    - Minimal exposure should be ensured

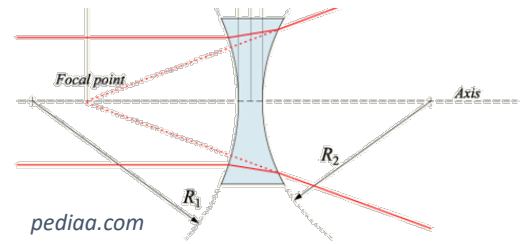
### Uses of EM waves

- Radio - TV and radio
  - o **Long wavelength, can travel far without losing quality**
- Micro - Satellite communication, cooking food
  - o **Can penetrate atmosphere to reach satellites**
- IR - Cooking food, infrared cameras
  - o **Transfers thermal energy**
- Visible - Fibre optics
  - o **Best reflection/scattering in glass (others have too short/long wavelengths)**
- UV - Sun tanning, energy efficient lamps
  - o **Radiates the least heat but more energy**
- X-ray - Medical imaging and treatment (and gamma)
  - o **Very high in energy, and can penetrate material easily**



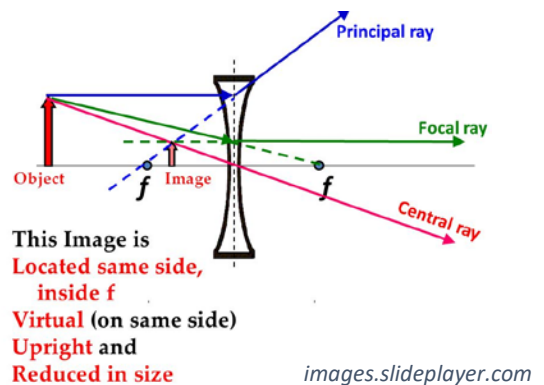
## Lenses (Physics only)

- If light passes through centre of lens, it does not change direction.
- Lenses are generally drawn as a dashed vertical line
- Focal points are points either side of the lens which light can converge at.
- Convex lenses can have virtual or real images (appear to be on same or opposite side as the real object respectively).
- Concave lenses can only have virtual images.



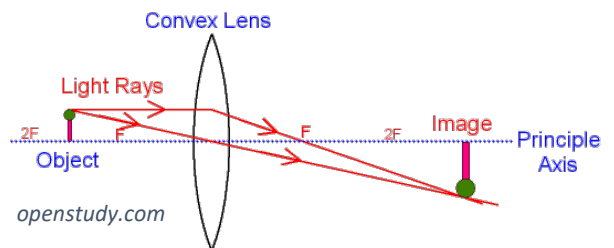
### Concave Lenses (Physics only)

- A concave lens “caves” inward
- They are thinner at centre than at edges
- Spreads light outwards
- Light appears to have come from the focal point
  - o Draw horizontal ray from top of object to lens
  - o Draw a faint line from focal point to point where the ray hits the lens
  - o The ray exits the lens along the same direction as the faint line
- It is used to spread out light further
  - o E.g. to correct short-sightedness
  - o As light is focused in front of the retina, so needs to be spread out slightly to be able to be focused onto retina



### Convex Lenses (Physics only)

- A convex lens is normally wider at centre
- They focus light inwards
- Horizontal rays focus onto focal point
- Used for magnifying glasses, binoculars
- Used to correct long-sightedness, as it focuses the rays closer



$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$



← How to represent a concave lens in a ray diagram

How to represent a convex lens in a ray diagram →



## Visible Light (Physics only)

Each colour within visible light spectrum has its own narrow band of wavelength and frequency

- Blue has a shorter wavelength, and higher frequency, than red
- Sunlight is a mix of all colours, and this mix appears white (i.e. white light is normal light)

Types of Reflection

- Specular
  - o Smooth surface gives a single reflection
- Diffuse
  - o Reflection off a rough surface causes scattering

Colour Filters

- This works by the filter absorbing every other colour
- And only letting certain wavelength (i.e. a certain colour) through

Opaque Colours

- An opaque object has colour, determined by the strength of reflection for different wavelengths
- Wavelengths which are not reflected are absorbed
  - o If all wavelengths reflect, it is white in colour
  - o If all wavelengths are absorbed, it appears black
  - o The wavelength which is absorbed = the colour which it appears

Objects that transmit light are either transparent or translucent (scatter most light and only let some through).

## Black Body Radiation and Space (Physics only)

All objects, regardless of temperature, emit and absorb infrared radiation.

- The hotter the body:
  - o The greater amount of radiation released per second (more powerful)
  - o The greater amount of shorter-wavelength radiation released (waves with more energy, like x-rays etc.)

A black body is an object that absorbs all the radiation it receives (does not transmit or reflect any)

- And therefore also emits all types of radiation

**A body at constant temperature:**

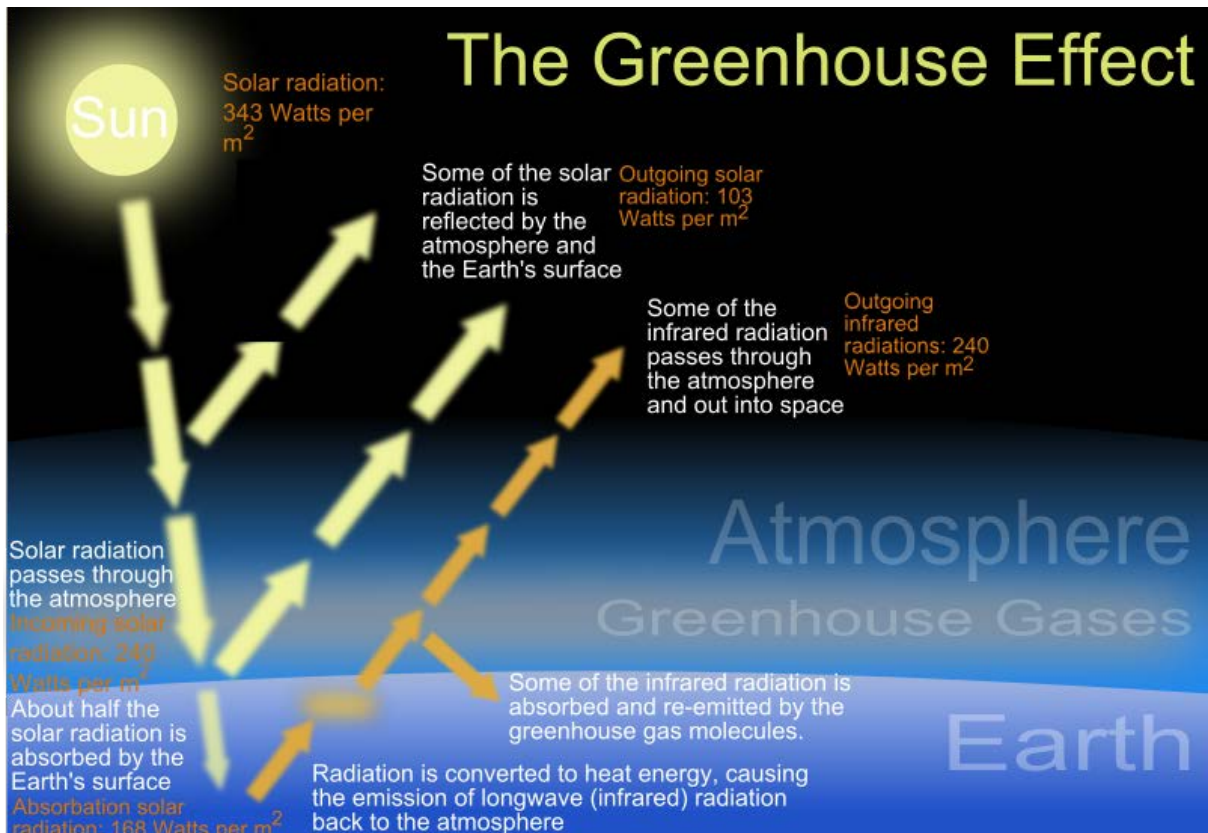
- **It is still radiating/receiving radiation**
- **But it is absorbing radiation at the same rate as it is emitting it**
- **Increasing temperature?**
  - o **It is absorbing more energy than it emits**
- **Cooling down?**
  - o **Energy is released at a greater rate than it absorbs**





### Earth (Physics only)

- Sun's energy is mostly absorbed by the earth's atmosphere, and some is reflected
- The amount of energy re-radiated and absorbed leads to Earth's temperature.



wikipedia.com – the atmosphere is responsible for keeping the earth at a constant temperature, by absorbing IR radiation from the sun and trapping IR re-radiated from the Earth.

