AQA GCSE Physics

Topic 6: Waves

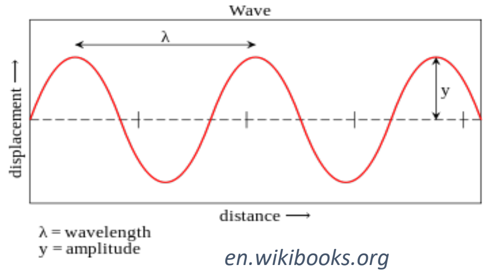
Notes

(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

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



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

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

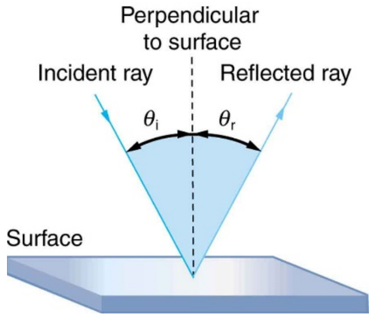
Types of Waves

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

Measuring velocity

- Sound in air
  - Make a noise at ~50m from a solid wall, and record time for the echo to be heard, then use speed = distance/time
  - 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
  - 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 λ is the wavelength in metres m.
  - 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 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
    - 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**
    - **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**
    - **The eardrum vibrates at the same frequency as the sound wave**
    - **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)**
    - **The small bones act as an amplifier of the sound waves the eardrum receives**
    - **As the fluid moves due to the compression waves, the small hairs that line the cochlea move too**
    - **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)

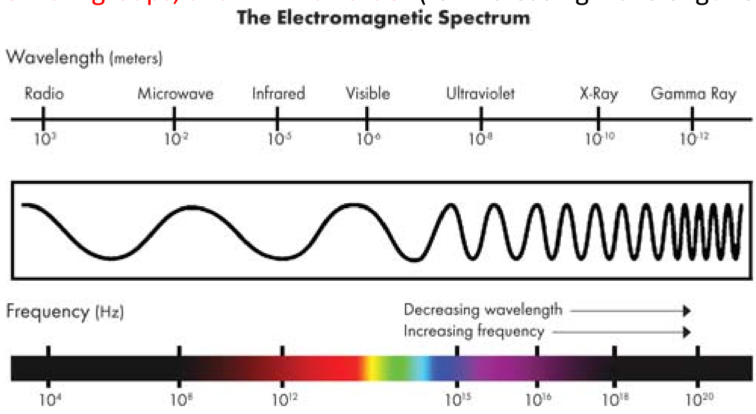
- Humans cannot hear below 20Hz or above 20kHz
- In the cochlea, the hairs attuned to the higher frequencies die or get damaged
  - Can be due to constant loud noise damaging these hairs over the years
  - Or can be due to the changes in the inner ear as you grow older
  - Smoking, chemotherapy, diabetes 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)



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- 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
    - Microwave source to food
    - Sun emits energy to Earth

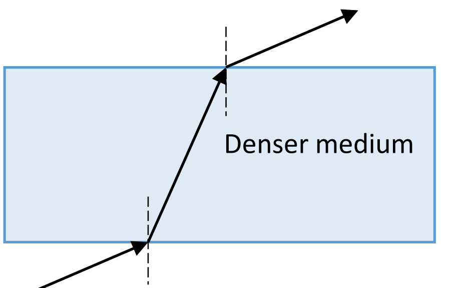
Relationships

- **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

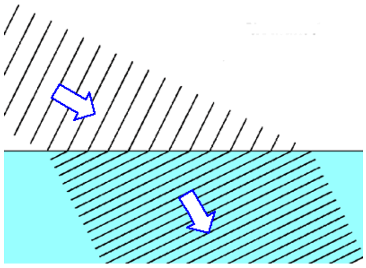


Both HT and FT are required to draw this diagram

- 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**
    - **E.g. Glass, will transmit/refract visible light**
    - **Absorb UV radiation**
    - **Reflect IR radiation**
    - **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**
    - **When light enters a denser medium, it slows down**
    - **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)**



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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)
  - When electrons move to a higher orbit (further from the nucleus)
    - The atom has absorbed EM radiation
  - 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

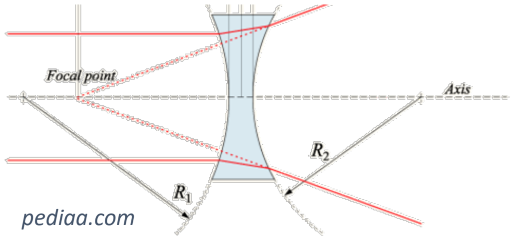
- UV light, X-rays and gamma can have hazardous effects on human body tissue.
- The effects depend on the type of radiation and the size of the dose
- Radiation dose: how much exposure leads to harm for a person
  - UV – skin ages prematurely, increasing risk of skin cancer
    - Sun cream prevents over-exposure in summer
  - 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
  - **Long wavelength, can travel far without losing quality**
- Micro - Satellite communication, cooking food
  - **Can penetrate atmosphere to reach satellites**
- IR - Cooking food, infrared cameras
  - **Transfers thermal energy**
- Visible - Fibre optics
  - **Best reflection/scattering in glass (others have too short/long wavelengths)**
- UV - Sun tanning, energy efficient lamps
  - **Radiates the least heat but more energy**
- X-ray - Medical imaging and treatment (and gamma)
  - **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.



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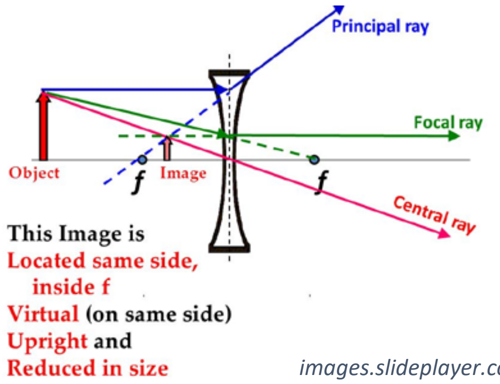
Concave Lenses (Physics only)

- 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



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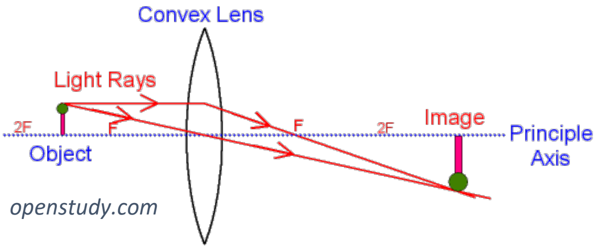
Convex Lenses (Physics only)

- 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



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

← 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
  - Smooth surface gives a single reflection
- Diffuse
  - 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
  - If all wavelengths reflect, it is white in colour
  - If all wavelengths are absorbed, it appears black
  - 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)

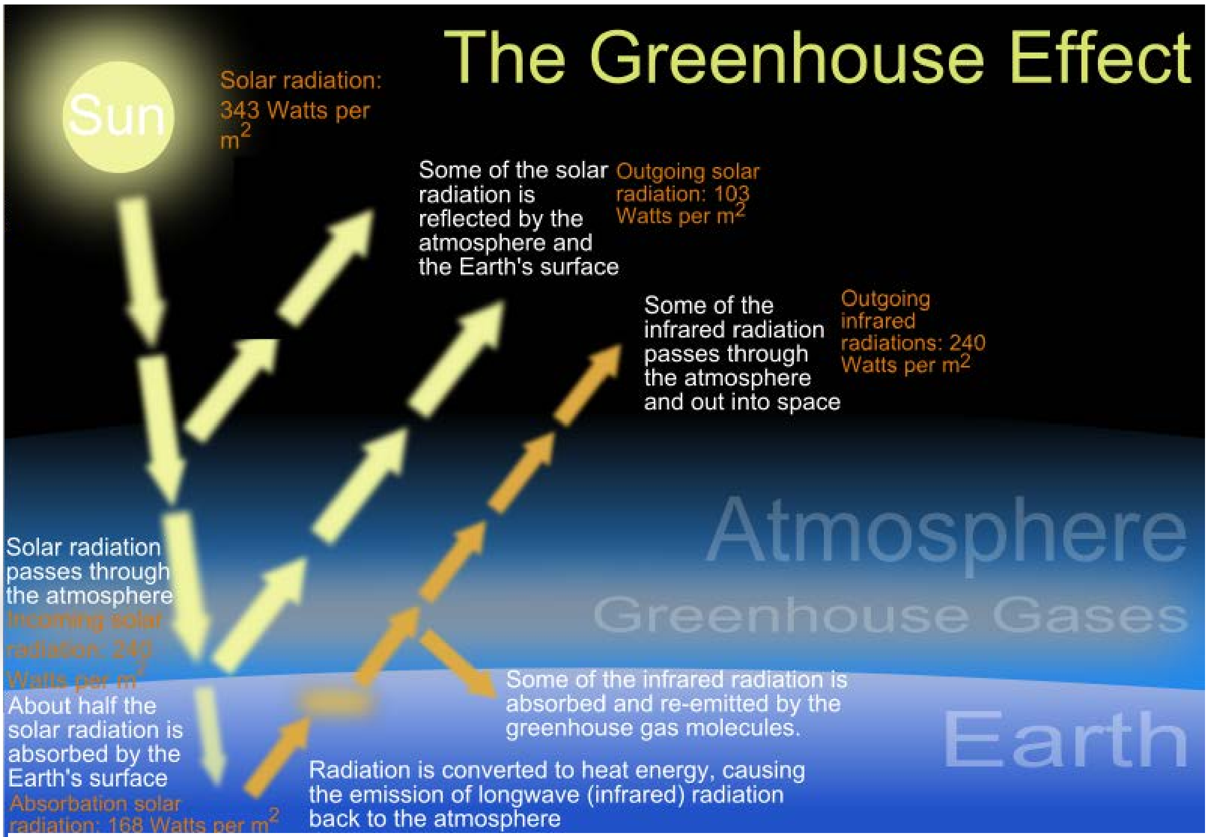
All objects, regardless of temperature, emit and absorb infrared radiation.
- The hotter the body:
  - The greater amount of radiation released per second (more powerful)
  - The greater amount of shorter-wavelength radiation released (waves with more energy, like x-rays etc.)

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?**
  - **It is absorbing more energy than it emits**
- **Cooling down?**
  - **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.