OCR (B) Physics GCSE

Chapter 1: Radiation and Waves

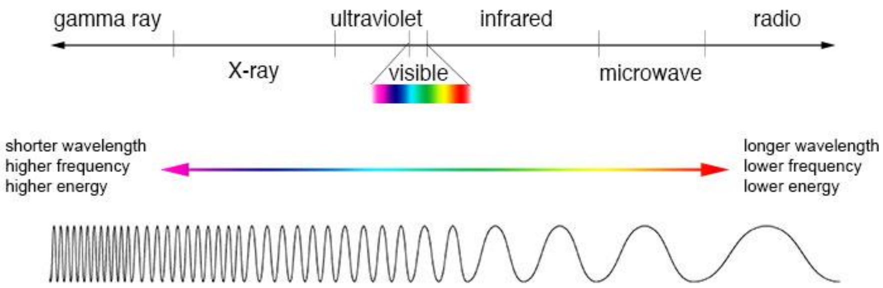
Summary Notes

(Contents in bold is for Higher Tier Only)

P1.1 What are the risks and benefits of using radiations?

Electromagnetic Radiation

The Electromagnetic (EM) Spectrum consists of 7 groups:



You must recall the order of the different waves from long to short wavelength, but the numerical value of wavelength is not required.

There are three main characteristics that separate each EM radiation:

1. Wavelength: From radio waves with the longest wavelength to gamma rays with the shortest
2. Frequency: From radio waves with the lowest frequency to gamma rays with the highest; our eyes can only detect a limited range of frequencies known as the visible light spectrum.
3. Energy: From radio waves with the lowest wavelength to gamma rays with the highest

Some common characteristics of EM radiation:

- Transverse Waves
- Do not need particles to move; they are radiation
- Travel at $3x10ms^{-1}$ through a vacuum
- Other objects may absorb, transmit or reflect EM radiation depending on its wavelength

EM Radiation transfers energy from source to absorber:

- Microwaves from source to food
- Sun emits energy to Earth

Production of EM Radiation

Changes in molecules, atoms and nuclei can generate and absorb radiation over a wide range of frequencies, including:

- Gamma rays are emitted from the nuclei of atoms
- X-rays, ultraviolet and visible light are generated when electrons in atoms lose energy
- Ultraviolet is absorbed by oxygen to produce ozone, which also absorbs ultraviolet, protecting life on Earth
- Infrared is emitted and absorbed by molecules

Ionisation

Gamma, X rays and high energy ultraviolet rays, have enough energy to cause ionisation when absorbed by some atoms.

- These radiation have small wavelength, high frequency, and high energy
- In an atom, electrons are arranged at different distances from the nucleus
- Arrangements may change with absorption or emission of EM radiation
- Atoms can become ions by loss of outer electrons
- Ionisation can cause cells to mutate, potentially causing cancer
- So radiotherapists, who constantly operate with gamma sources, try to maintain minimal exposure by leaving the room etc.
- Pilots, flying at high altitudes where there is more UV, have an increased risk of cancer

Uses of Electromagnetic Radiation

EM Radiation	Use	Explanation
Radio	Communications	Long wavelength, can travel far without losing quality
Microwaves	Cooking	Heats the water or fat in foodstuffs Can penetrate atmosphere to reach satellites
Infrared	Cooking food, infrared cameras, short range communication, remote	Transfers thermal energy
Visible	Illuminate things Fibre optics	Best reflection/scattering in glass (others have too short/long wavelengths)
UV	Sun tanning, energy efficient lamps, sterilisation	Radiates the least heat but more energy, kills bacteria
X ray	Medical imaging and treatment	Very high in energy, and can penetrate material easily
Gamma	Medical Treatment	Used to kill cancer cells in radiotherapy

Radio waves

- **Radio waves can be produced by oscillations in electrical circuits.**
- **When radio waves are absorbed they create an alternating current (AC) in the conductor, at the same frequency as the radio waves. This can be used to detect radio waves.**

P1.2 What is Climate Change and what is the Evidence for it?

Emission of EM Radiation

All objects emit electromagnetic radiation with a principal frequency that increases with temperature. Intensity and wavelength distribution of any emission depends on their temperatures. The hotter the body...

- The greater amount of radiation released per second (increased power and intensity)
- The greater amount of shorter-wavelength radiation released (waves with more energy, x-rays etc.)

Temperature and Radiation

The temperature of a body is related to the balance between incoming, absorbed and emitted radiation.

A body at constant temperature...

- **Is still radiating/receiving radiation**
- **But is absorbing radiation at the same rate as it is emitting it**

A body increasing in temperature:

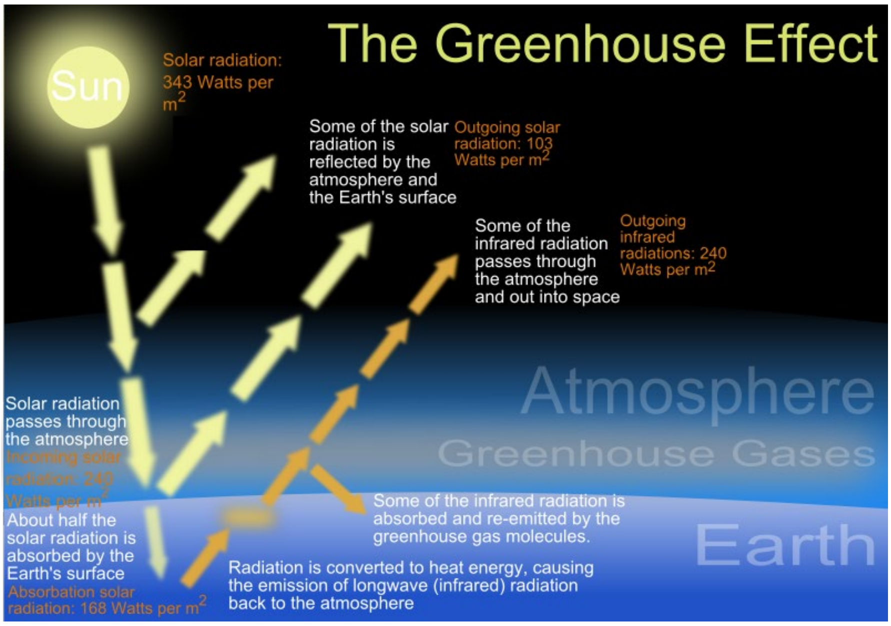
- **Is absorbing more energy than it emits**

A body cooling down:

- **Is releasing energy at a greater rate than it absorbs**

Temperature of the Earth

- **The sun's energy is mostly absorbed by the earth's atmosphere**
- **Some is reflected**
- **The amount of energy re-radiated and absorbed leads to Earth's temperature.**

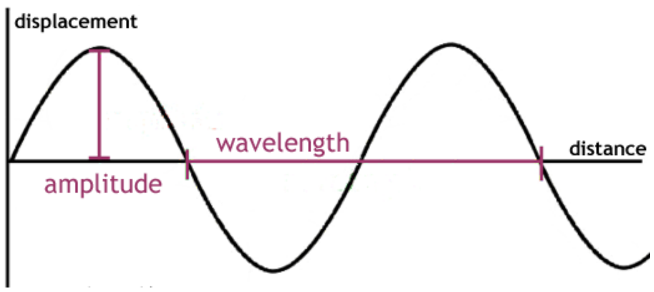


P1.3 How do Waves Behave?

Wave Motion

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

Wave Equations



$$V = f \times \lambda$$

- Frequency increases, velocity increases
- Wavelength increases, velocity increases

$$F = \frac{1}{T}$$

- Period is inversely proportional to frequency
- Smaller period = higher frequency = greater velocity

Types of Waves

- Transverse waves
  - E.g. light, or any electromagnetic wave, waves on a rope
  - Have peaks and troughs
  - Vibrations are at right angles to the direction of travel
- Longitudinal waves
  - E.g. sound waves through air, oscillations on a spring
  - 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.

- For sound, the air particle regions move right then left due to compressions and rarefactions, and the air pressure causes adjacent regions of air to move too, hence the wave travels through the air, and doesn't cause a single region of air to just move.
- If a ping pong ball is placed in a ripple tank, it doesn't get carried by the waves; the particles simply move up and down, not in the direction of the wave.

Investigating 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.
- Or 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.

Ripple Tanks

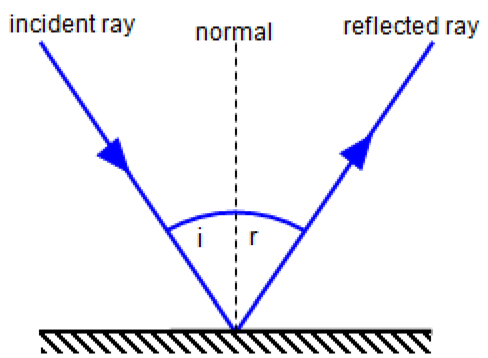
- These are shallow glass tanks with a needle or paddle which oscillates, producing water waves at a determined frequency.
- If light is shone through it, dark/light patches will appear underneath it, as light passes through crests and troughs respectively (when light passes through a crest, it passes through the most amount of water possible, so is scattered the most and appears the darkest).
- By counting the number of times a dark (maximum) passes through the point in 60 seconds, and dividing by 60, you can get the number of oscillations per second (frequency).
- Wavelength can be measured by using a stroboscope at the same frequency as the waves, so the pattern of waves appears fixed on the screen. Then distance between two maxima can be measured to calculate wavelength.
  - $v=f\lambda$
- Also, one person can draw on the screen a line, keeping the pencil in line with a certain maximum, and then another person record the time taken to draw the line. Then use equation of distance / time = speed.

Modelling in Ripple Tanks

- Reflection can be shown by the waves hitting a wall
- Refraction can be shown by placing a thick glass sheet in the tank (only covering some of tank floor)
  - The depth of water becomes shallower here
  - So as speed depends on depth, the ripples slow down, mimicking how waves slow down when entering a denser medium

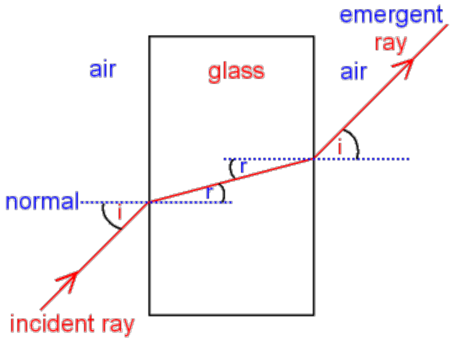
Reflection

- Waves will reflect off a flat surface
- The smoother the surface, the stronger the reflected wave
- 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



Refraction

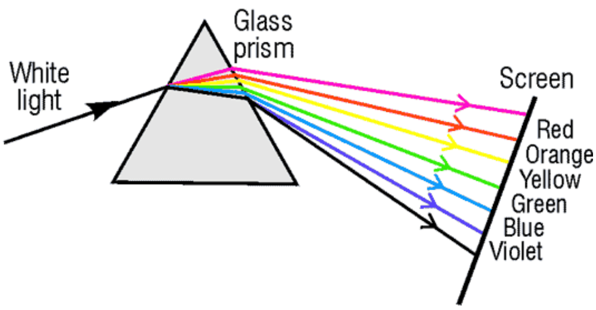
- If entering a denser material, light slows down and bends towards the normal
- Shorter wavelengths slow down more than longer wavelengths (e.g. Blue light slows down more than red)
- If entering a less dense material, it speeds up and bends away from normal



Refraction of Light through a Prism

Why does dispersion occur when white light passes through a prism?

- The different wavelengths refract a different amount, and therefore spread out to create a rainbow effect
- **When refracting, the speed and wavelength decreases in a denser material**
- **the horizontal lines show the "wave-fronts" of the waves (imagine each line is each maxima of the transverse wave)**



Passing from air to glass (denser medium)

- **Wave speed decreases**
- **Wavelength decreases**
  - **This is because $v=f\lambda$ must hold true; as frequency is constant, wavelength must decrease as speed decreases**
  - **Speed decreases because it is travelling through a more dense medium, so it cannot travel as fast**
  - **The energy of the wave must be constant, because of conservation of energy. This means frequency cannot change, so the colour of the light does not change either**

P1.4 What happens when Light and Sound meet Different Materials? (Physics Only)

Interactions (Physics only)

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

Transmission (Physics only)

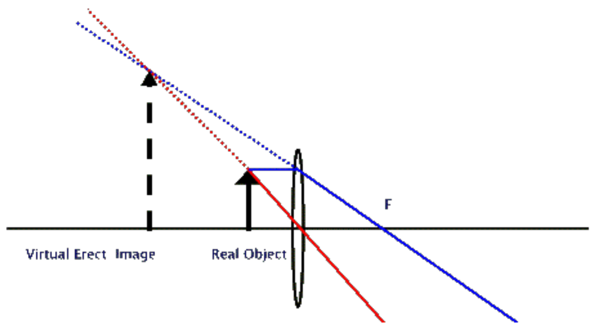
- Waves will pass through a transparent material
- The more transparent, the more light will pass through the material
- It can still refract, but the process of passing through the material and still emerging is transmission
- Waves will not pass through an opaque material

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 re-emitted
- The absorbed light will then be re-emitted over time as heat
- So that particular frequency has been absorbed (removed from the light)
- If a material appears green, only green light has been reflected, and the rest of the frequencies in visible light have been absorbed

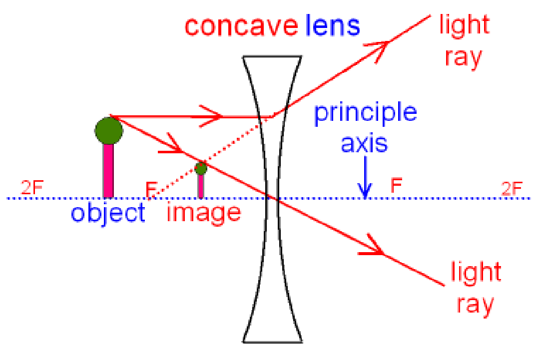
Lenses (Physics only)

- If light passes through the centre of the 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 (on the same side of the lens as the object) or real (on the opposite side) images.
- Concave lenses can only have virtual images.



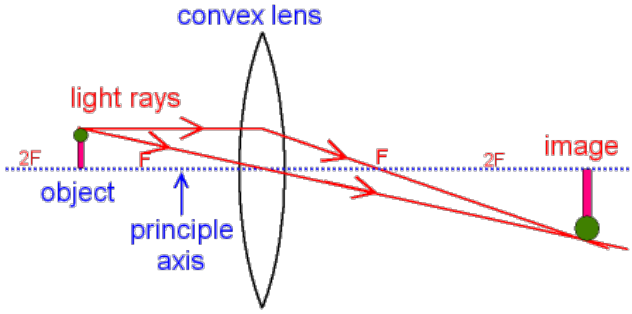
Concave Lenses (Physics only)

- A concave lens "caves" inward
- They are thinner at the centre than at the edges
- Spreads light outwards
- Light appears to have come from the focal point
    - Draw horizontal ray from top of object to lens
    - Draw a faint line from focal point to point where the ray hits the lens
    - The ray exits the lens along the same direction as the faint line
- It is used to spread out light further
- Used to correct short-sightedness
    - Light is focused too far in front of the retina
    - It needs to be spread out slightly so it focuses further away, focusing onto the 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



$$Magnification = \frac{Image\ Height}{Object\ Height}$$

Visible Light (Physics only)

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

- Blue has a shorter wavelength and higher frequency than red
- Sunlight (and white light) is a mix of all colours, which appears white

Types of Reflection

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

Colour Filters

- This works because the filter absorbs every other colour
- And transmits only the desired 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 are reflected, it is white in colour
  - If all wavelengths are absorbed, it appears black
  - The wavelength which is reflected = the colour which it appears

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

How the Ear Works (Physics only)

- Sound waves can travel through solids causing vibrations in the solid.
- The outer ear collects sound and channels it down the ear canal.
- It travels down as a pressure air wave
- The waves hit the eardrum - a 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 (stirrup bones) also vibrate at the same frequency
- The vibrations are 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
  - 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
    - Each hair is attached to 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 the sound.

Limitations of Human Frequency Range (Physics only)

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

Ultrasound (Physics only)

- When ultrasound waves reach a boundary between two media, they are partially reflected
- The remainder of the waves continue and pass through
- 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 how far they have travelled
  - Remember to divide by two, as they have travelled the distance twice, from source to point of reflection and then from point of reflection back to source
- 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

Earthquake Waves (Physics Only)

Infrasound (aka Seismic waves) is the opposite of ultrasound – it is a sound wave with a frequency lower than 20Hz.
There are two types: 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 and slower moving, only passing through solids.
- 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 (Physics Only)

- 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 can be used to work out whether there is a shoal of fish below the ship, or how far the seabed is below the ship.