

CIE Physics IGCSE

Topic 3: Waves Summary Notes

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General wave properties

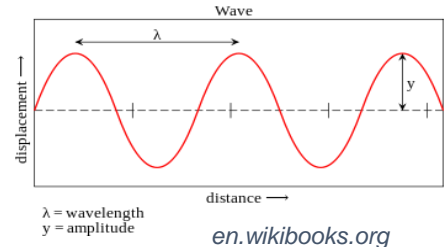
Waves transfer energy without transferring matter; particles oscillate about a fixed point.

- Amplitude – the **distance** from the **equilibrium** position to the **maximum displacement**
 Wavelength – the **distance** between a **point** on one wave and the **same point** on the next wave
 Frequency – the **number of waves** that pass a single point **per second**
 Speed – the **distance** travelled by a wave **each second**

- **Speed is related to frequency and wavelength**
by: $speed = frequency \times wavelength$ $v = f\lambda$

Types of waves:

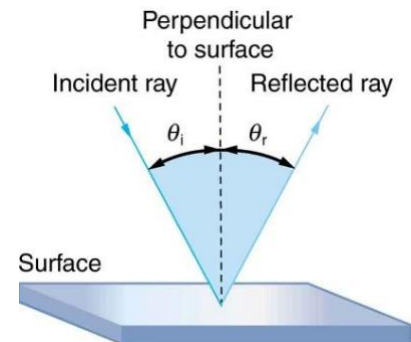
- **Transverse** waves
 - Has **peaks** and **troughs**
 - Vibrations are at **right angles** to the direction of travel
 - An example is light
- **Longitudinal** waves
 - **Consists of compressions (particles pushed together) and rarefactions (particles moved apart)**
 - Vibrations are in the **same direction** as the direction of travel
 - An example is sound



A **wavefront** is a surface containing points affected in the **same way** by a wave at a given time such as crests or troughs.

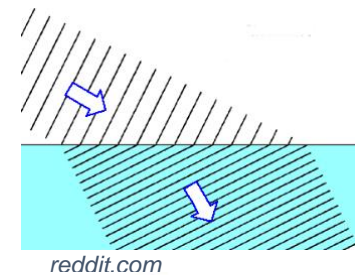
Reflection:

- Waves **reflect** off smooth, plane surfaces rather than getting absorbed
 - Angle of incidence = angle of reflection
- Rough surfaces scatter the light in all directions, so they appear matte and unreflective
- Frequency, wavelength, and speed are all **unchanged**



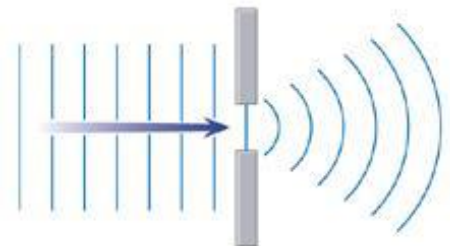
Refraction:

- The **speed** of a wave **changes** when it enters a new medium
- If the wave enters a **more optically dense** medium, its speed **decreases** and it bends **towards** the normal
- If the wave enters a **less optically dense** medium, its speed **increases** and it bends **away from** the normal
- In all cases, the frequency stays the same but the wavelength changes.



Diffraction:

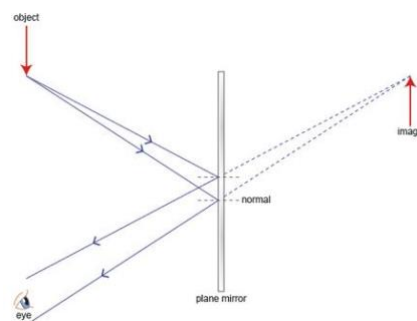
- Waves **spread out** when they go around the sides of an obstacle or through a gap
- **The narrower the gap or the greater the wavelength, the more the diffraction**
- Frequency, wavelength, and speed are all **unchanged**



Light

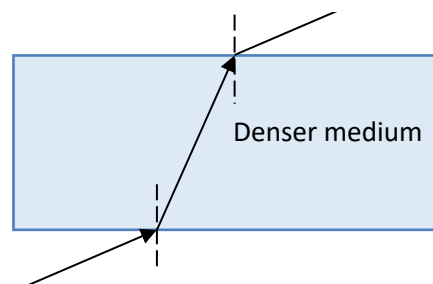
Reflection

- When light is reflected off a plane mirror, it forms an image with these characteristics:
 - Upright
 - Same distance from the mirror as the object
 - Same size
 - **Virtual**



Refraction

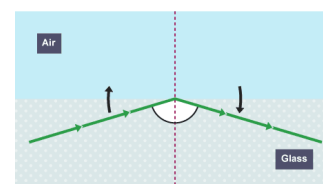
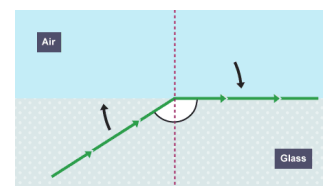
- **Refraction** can be shown when light is passed through a glass slab at an angle to its normal
- When light enters a more optically dense medium, the **angle of incidence** (the angle between the incident ray and the normal) is **greater** than the **angle of refraction** (the angle between the refracted ray and the normal). The **opposite** is true when light enters a less optically dense medium.
- The **refractive index n** of a medium is defined as the **ratio between the speed of light in a vacuum and the speed of light in the medium**: $n = \frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}}$
- **Snell's law** relates the angle of incidence and the angle of refraction to the refractive index by: $n = \frac{\sin i}{\sin r}$ where i is the angle of incidence and r is the angle of refraction.



Total internal reflection:

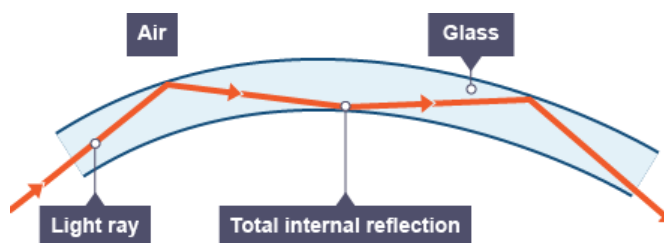
- At a certain angle of incidence called the **critical angle**, the light will travel along the boundary between the two media.
- **Total internal reflection** occurs when the angle of incidence is **greater** than the critical angle and the light **reflects** back into the medium.
- For total internal reflection to occur, the light must also be travelling from a **more optically dense medium** into a **less optically dense medium** (most common example is glass to air).
- The **critical angle can be related to the refractive index by:**

$$n = \frac{1}{\sin c}$$



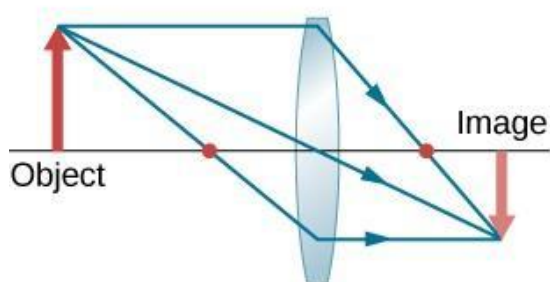
Optical fibres:

- An **optical fibre** is a long thin rod of **glass** surrounded by cladding which uses **total internal reflection** to transfer information by light, even when bent.
- Extensive use in **medicine** (endoscopes, inside-body flexible cameras) and **communications** (high speed data transfer).



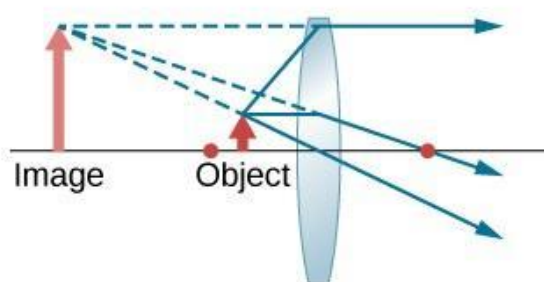
Converging lens:

- A **converging lens** is a transparent block which brings light rays together at a point called the **principal focus** by utilising refraction.
- The **focal length** is the distance between the centre of the lens and the principal focus.
- The **image formed by a converging lens can be either real or virtual.**
 - **Real images** are formed when the distance of the object from the centre of the lens is greater than the focal length. They are images where light **actually converges to a position and can be projected** onto a screen.
 - **Virtual images** are formed when the distance of the object from the centre of the lens is smaller than the focal length. They are images where light only **appears to have converged** and they **cannot be projected** onto a screen.
- You can draw **ray diagrams** for real images (shown on the left below) and **virtual images** (shown on the right below).



Converging lens
Real image

(a)



Converging lens
Virtual image

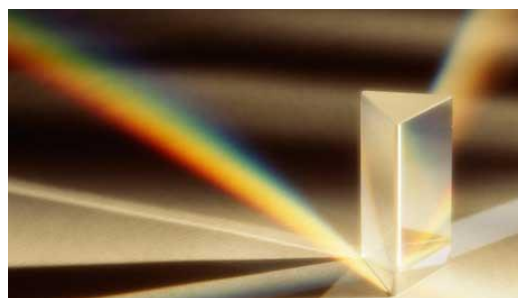
(b)

- The image formed is **enlarged/same size/diminished** and **upright/inverted**.
 - The image on the left above is diminished and inverted.
 - The image on the right above is enlarged and upright.
- Converging lenses are used in **magnifying glasses** and binoculars (to enlarge the image).

Dispersion

When white light is passed through a glass **prism**, it splits up into its constituent **colours**. This happens because the **different colours** travel at **different speeds** in the glass, so they **refract** by different amounts.

- The seven colours in order of decreasing wavelength are red, orange, yellow, green, blue, indigo and violet (**ROYGBIV**).
- The **greater the wavelength**, the slower the speed in glass and the **greater the refractive index**.



Light of a **single frequency** is described as **monochromatic**.

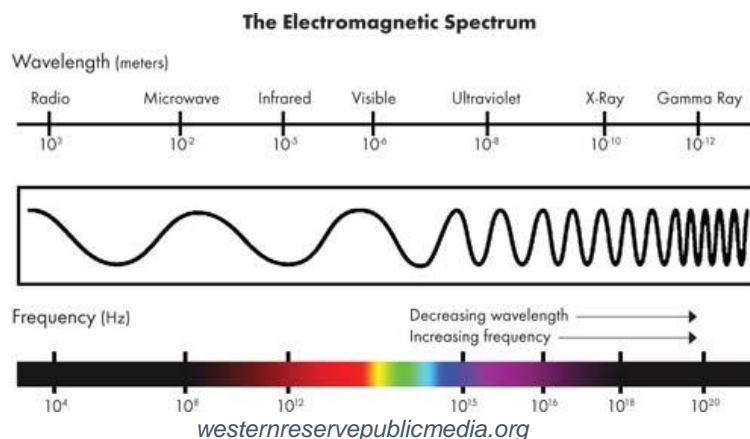


Electromagnetic spectrum

Properties of electromagnetic waves:

- **Transverse** waves
- Do **not** need a medium
- All electromagnetic waves travel with the **same high speed** of $3.0 \times 10^8 \text{ ms}^{-1}$ in a vacuum and **approximately the same speed** in air.

You need to learn the main groups of the electromagnetic spectrum in order of wavelength.



As speed is constant for all electromagnetic waves, **as wavelength decreases, frequency must increase**. The higher the frequency of an EM wave, the greater its **energy**.

Uses of electromagnetic waves:

- **Radio waves** are used for **radio and television communications**. They have a long wavelength and are reflected by the ionosphere.
- **Microwaves** are used for **satellite communication** and in microwave oven. They pass through the ionosphere and penetrate deep into food.
- **Infrared radiation** is used in **remote controllers** and **infrared cameras**.
- **Visible** light is used in fibre optics.
- **Ultraviolet** light is used in tanning beds.
- **X-rays** are used in **medical imaging** and in **security** as they can penetrate material easily.
- **Gamma radiation** is used in medical treatment due to its high energy.

Hazards:

- Too much exposure to ultraviolet light skin increases the risk of **skin cancer**.
 - Sun cream prevents over-exposure in summer.
- X-rays and gamma rays are **ionising** radiation that can cause mutations leading to **cancer**.
 - Exposure to these kinds of radiation should be minimised.
- Microwaves can cause **internal heating** of body tissues.
- Infrared radiation can cause **skin burns**.



Sound Waves

Sound waves are **longitudinal** waves created by **vibrating** sources. A **medium** is needed to transmit sound waves (such as air).

- The **greater the amplitude** of a sound wave, the **louder** it is.
- The **greater the frequency** of a sound wave, the **higher its pitch**.

To measure the **speed of sound** in air, you can make a noise at a known, large **distance** from a solid wall and record the **time** for the **echo** (reflected sound) to be heard, then use $\text{speed} = \text{distance}/\text{time}$, taking into account the fact that the sound had to go there and back.

The speed of sound in air is 343 ms^{-1} , the speed of sound in water is 1493 ms^{-1} , and the speed of sound in steel is 5130 ms^{-1} .

The range of audible frequencies for a healthy human ear is 20 Hz to 20000 Hz. **Ultrasound** is sound with a frequency greater than 20000 Hz:

- When ultrasound reaches a **boundary** between two media it is **partially reflected** back. The remainder of the waves continue to pass through.
- A transceiver can emit ultrasound and record the reflected waves to find the **distance** of things below the surface.
- Ultrasound is used for things such as SONAR and for medical imaging without using ionising radiation.

