WJEC (Eduqas) Physics A-level

Topic 3.3: Refraction of Waves

Notes

Refractive Index

The refractive index of a medium is the ratio of the speed of light in a **vacuum** to the speed of light in that medium.

$$n = \frac{c}{v}$$

For diamond, the refractive index is 2.42. Therefore, light travels 2.42 times slower in diamond compared to a vacuum.

To calculate the speed of light in diamond:

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n} = \frac{3.0\times10^8}{2.42} = 1.2 \times 10^8\ m/s$$

Using the definition, we have:

$$nv = c$$

As c is a constant, nv is constant and therefore:

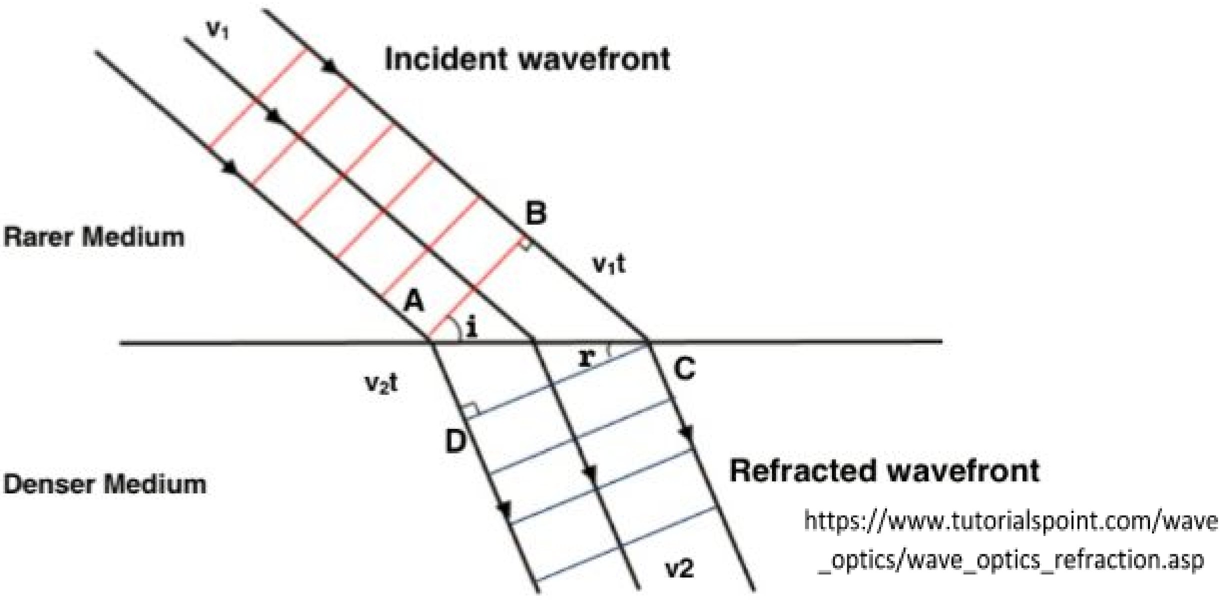
$$n_1 v_1 = n_2 v_2$$

Snell's Law

Snell's law tells you how the angles of incidence and refraction are related to the refractive indices of two mediums when light passes from one to the other.

$$n_1 sin(\theta_1) = n_2 sin(\theta_2)$$

A derivation can be done using the idea of plane waves.



Using the notation given in the diagram, for the new plane waves to form, the two distances $v_2 t$ and $v_1 t$ are both travelled during the time

t because as the light at A passes into the denser medium, light at B has to travel an extra distance $v_1 t$ to meet the wave front at C.

Let the distance AC equal d.

$$d sin(r) = v_2 t$$

$$d sin(i) = v_1 t$$

$$\Rightarrow \frac{sin(r)}{sin(i)} = \frac{v_2}{v_1}$$

$$\Rightarrow n_2 sin(r) = n_1 sin(i)$$

This can then be written, with different notation, as:

$$n_1 sin(\theta_1) = n_2 sin(\theta_2)$$

Total Internal Reflection

Total internal reflection (TIR) is when the light is incident on a medium but instead of refracting, **reflects off the medium boundary**. This happens when the angle of incidence is above a specific angle – called the **critical angle**.

Using Snell's law we can find the critical angle for a medium.

$$n_1 sin(\theta_1) = n_2 sin(\theta_2)$$

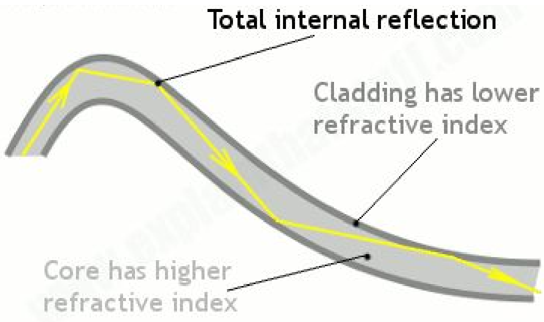
$$n_1 sin(\theta_c) = n_2 sin(90°)$$

$$sin(\theta_c) = \frac{n_2}{n_1}$$

θ_c is the critical angle. Note that we have total internal reflection because the angle of refraction is $90°$.

Optical Fibres

Optical fibres are fibres which transfer data using light and total internal reflection. Light travels through these because every time the light comes across a boundary between the core and the cladding, it **reflects internally**. Therefore, it **never leaves the fibre**. The light will then travel a short distance before coming across another boundary and repeating the process.



Multimode Fibres

Multimode fibres are just fibres which have **multiple paths of light travelling** within them. Because different paths are taken, the modes (the individual paths) have varying propagation velocities. This means that the signal does not arrive at the same time and appears distorted which is called multimode dispersion. Shorter distances should be used with multimode fibres such that the effect of this is smaller. Also, you cannot have too many modes in the fibre otherwise the multimode dispersion effect will become exaggerated and so the **rate of data transfer is limited**.

Monomode Fibres

These are optical fibres which have only a single mode which is parallel to the wire (through the centre). These have **higher data transfer rates and can transfer data over much longer distances** because there is little multimode dispersion (resulting from the single light ray and smaller core).