WJEC (Eduqas) Physics A-level

Topic 3.2: Wave Properties

Notes

Diffraction

Diffraction is a phenomenon observed when waves pass through a gap or slit – **they spread out**. The extent to which they spread out depends on the relative sizes of the wavelength of the wave and the width of the gap.

When the wavelength, λ **is much smaller than the gap width**, there is **very little diffraction** and the main beam spreads out through less than $180°$.

When the wavelength, λ **is greater than or equal to the gap width, the beam spreads out in approximately semi-circular wave fronts** (so has spread out through $180°$).

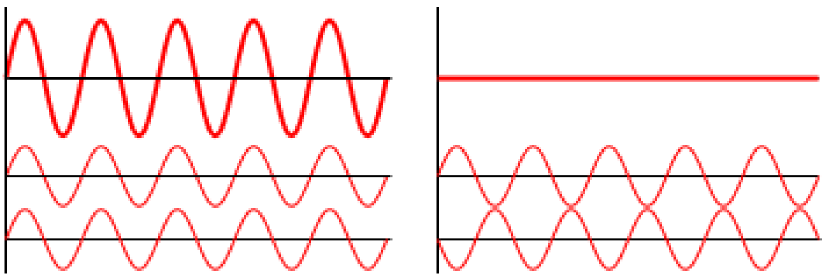
This explains why we can hear sound round corners but cannot see round them. The wavelength of light is way too small compared to the gap (e.g. a door) whereas the wavelength of light is comparable to it.

Two Source Interference

Two source interference is when waves from two different sources superpose and form a new wave. The two waves need to have the same frequency. The amplitude of this resultant wave depends on **how the two waves meet**.

If the waves meet in phase, the **amplitudes add up** and the resultant wave has an amplitude of the sum of the original amplitudes – called **constructive interference**.

If the waves meet in anti-phase, the **amplitudes cancel out** and the resultant wave has a zero amplitude – called **destructive interference**.



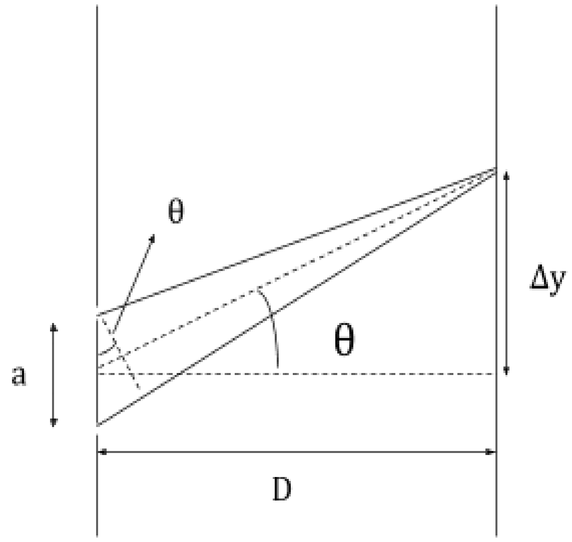
https://en.wikipedia.org/wiki/Wave_interference#/media/File:Interference_of_two_waves.svg

The **principle of superposition** is more general. It says that the resultant waves displacement at a time is given by the sum of the two individual displacements (taking note of positive or negative displacements).

Young's Double-Slit Experiment

Young did an experiment which used both above concepts. He caused a wave source to diffract through two slits artificially creating two sources which could interfere with each other and produce a pattern on a screen of bright fringes and dark fringes.

The experiment is important because it showed that light does indeed behave like a wave and **challenged the idea that light was made up of particles**.



This is a diagram of the double slit experiment. When the two rays meet on the screen, they either undergo constructive or destructive interference or some other partial interference.

Path difference is the difference in the **length of the path which waves travel**. This difference in paths is another way of looking at phase difference because the path difference can be used to calculate the phase difference and vice versa.

For constructive interference, the phase difference needs to be an integer multiple of 2π but as 2π is one whole wave cycle we say that the path difference needs to be an integer multiple of the wavelength $= n\lambda$.

In the above diagram we will assume that the two rays are parallel because the angle between them will be very small. Therefore, we can say that the difference in their path lengths, the path difference is equal to $a\sin(\theta)$. Hence for constructive interference,

$$n\lambda = a\sin(\theta)$$

In the diagram above, the two angles marked θ are **approximately** equal because the theory is based on the screen being an infinite distance away and therefore the dotted line in between the two light rays is approximately perpendicular to the line joining the top slit to the bottom ray. For $D \gg \Delta y$, $\sin(\theta) \approx \tan(\theta)$.

Using some basic trigonometry, we can deduce that:

$$\tan(\theta) = \frac{\Delta y}{D}$$

=> $\sin(\theta) \approx \frac{\Delta y}{D}$ and $a\sin(\theta) \approx \frac{a\Delta y}{D}$.

Therefore, substituting in, we have for the first maximum:

$$\lambda = \frac{a\Delta y}{D}$$

Diffraction Gratings

Using a diffraction grating with a small slit separation means that the beam **spreads further** apart than with two slits (in Young's experiment). Also, the more slits used the **sharper the pattern** is on the screen making it easier to take measurements of maximum and minimum distances.

Coherent Sources

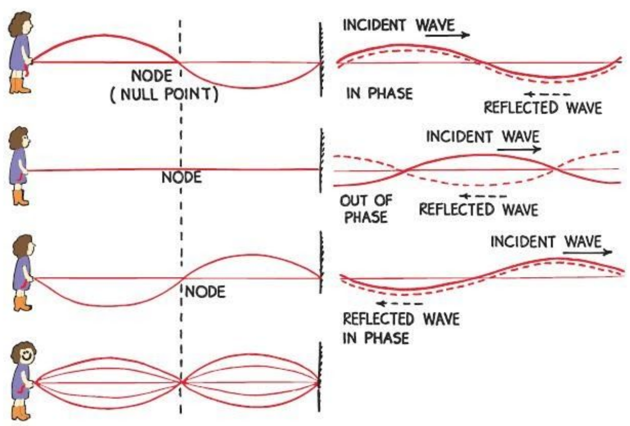
Coherent wave sources are sources which are **monochromatic** (of only one wavelength) and have a constant phase difference. They have wave fronts continuously across the width of the beam also which means you could travel from one side of the beam to the other across one wave front.

A laser is a coherent light source. However, filament lamps are incoherent because of the random electron transitions between atoms causing changes in phase difference.

For two source interference (see above) to occur, the sources must be coherent, and the oscillations must be in the same direction.

Stationary Waves

Stationary waves are waves which store energy instead of transferring energy like progressive waves do. These waves are formed when you have two waves of equal frequency and amplitude travelling in opposite directions which superpose creating a sequence of **nodes and anti-nodes**.



http://fun-phys.blogspot.com/2016/06/standing-waves-on-string-simulation.html

The nodes are where there is no movement and the anti-nodes are where there is maximum oscillation. The distance between adjacent nodes (called the **inter-nodal distance** is equal to $\frac{\lambda}{2}$.