WJEC (Eduqas) Physics A-level

Topic 3.1: Nature of Waves

Notes

Transverse and Longitudinal Waves

In all types of progressive waves, **energy is transferred without a transfer of matter**.

Transverse

Particles oscillate in a direction **perpendicular** to the direction of energy transfer and direction of wave propagation. The particles do not move at all along the direction of travel of the wave.

Longitudinal

These waves have the particles oscillating parallel to the direction of travel. They do not move in the direction perpendicular to the direction of travel.

Polarisation

Polarisation is a phenomenon that can be observed with **transverse** waves. Because the oscillations of particles must be perpendicular to the direction of travel, there are multiple orientations which exist.

To polarise a wave means to limit the direction of these oscillates to only one direction. All particles will then oscillate in the same plane.

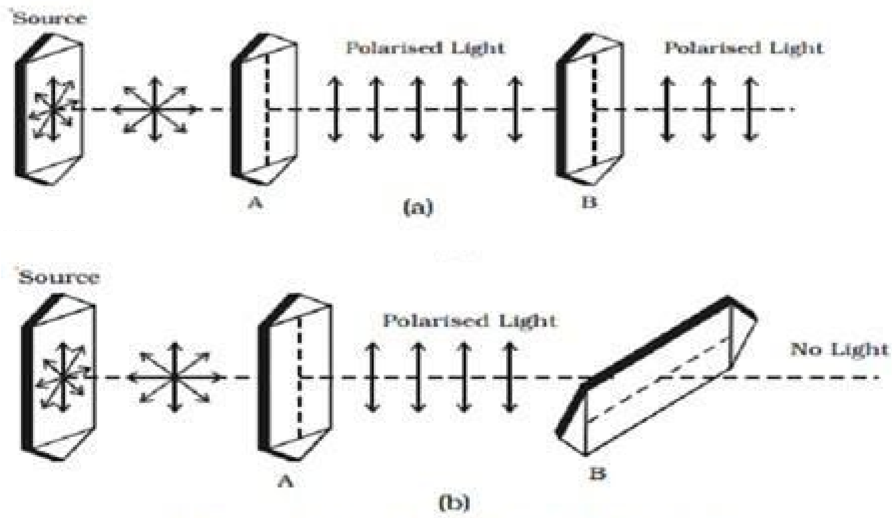


Fig . Polarisation of transverse waves

The diagram above shows this process with the arrows showing the **direction of oscillation** of the particles. At the source, we can see that all the directions of oscillation are **perpendicular to the direction of travel**. When the wave passes through a polarising filter (A or B in the diagram above), only specific planes of oscillations are allowed through.

For example, in (a), filter A only allows vertically polarised light through. Hence, the new light oscillates in the vertical plane. However, when this vertically polarised light reaches filter B, **all the light passes through**. This is because filter B only allows vertically polarised light through and the light from filter A is oscillating entirely in the vertical direction.

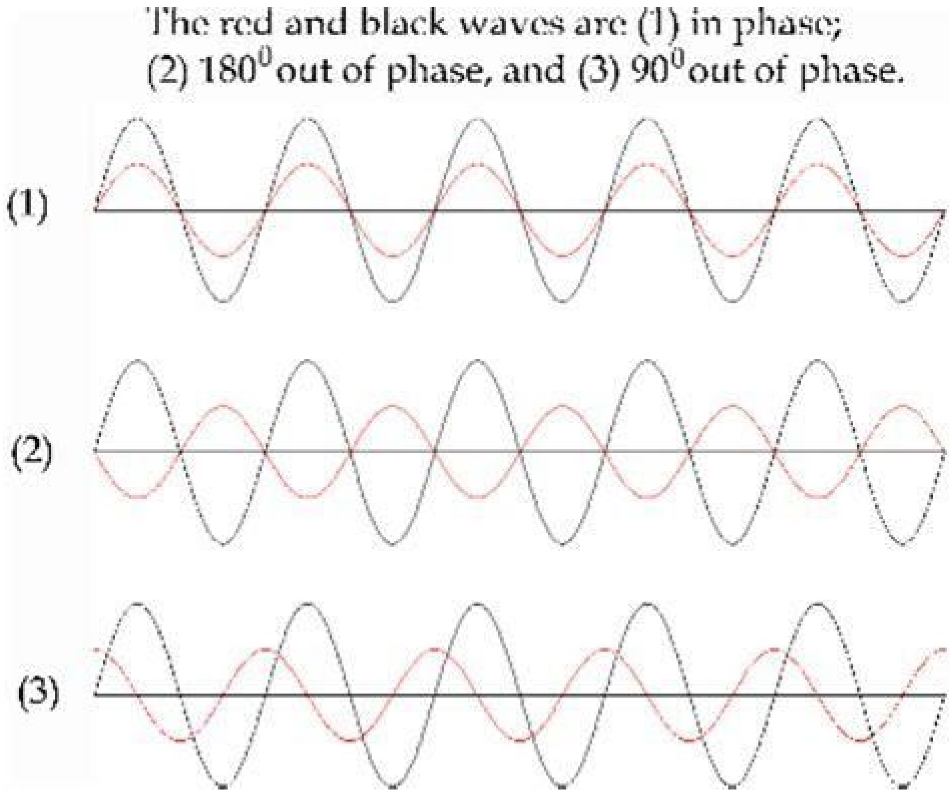
In (b), filter A only allows vertically polarised light through. Hence, the new light oscillates in the vertical plane. However, when this vertically polarised light reaches filter B, **no light passes through**. This is because filter B only allows horizontally polarised light through.

Phase and Anti-phase

Phase is the position of a point on a wave in terms of its position in the wave cycle. For two waves to be in phase or in anti-phase they must have the same frequency.

To be in **phase**, at one instant, the oscillations of particles in the first wave must be in the same position of the cycle as the oscillations in the second wave.

To be in **anti-phase**, at one instant, the oscillations of particles in the first wave must be in the opposite position of the cycle as the oscillations in the second wave.



https://www.quora.com/What-exactly-are-in-phase-and-out-of-phase-in-terms-of-waves

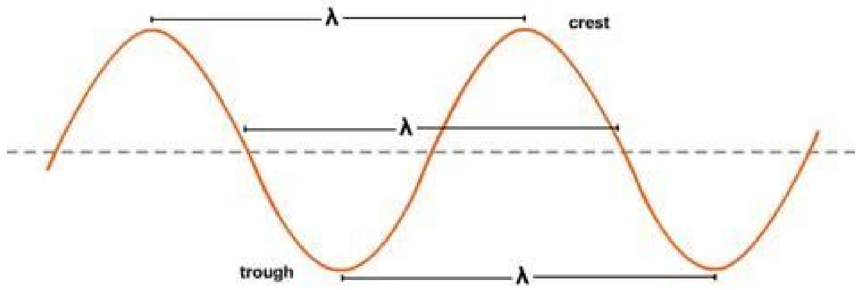
If the waves are not in-phase or anti-phase they will be out of phase. This means they are not in phase by some fraction of a wave cycle. Often, phase difference (the amount by which waves are out of phase) is expressed in degrees or radians – $360°\ or\ 2\pi$ radians being a full cycle.

Therefore, for waves in phase they must have a phase difference which is an integer multiple of 2π radians i.e. $2\pi n$.

For waves in anti-phase they must have a phase difference which is an integer multiple of 2π, plus π radians i.e. phase difference of $2\pi n + \pi = (2n+1)\pi$.

For waves out of phase, you need to compare the points on the wave to find out the phase difference. In (3) above, we can see that the peaks of the waves are a quarter of a wave cycle apart and a quarter of a wave cycle is $90°$.

Wave Terminology



https://en.m.wikibooks.org/wiki/IB_Physics/Oscillations_and_Waves

The distance between two peaks or two troughs on a wave is called the **wavelength** and is often given by the symbol λ.

The **equilibrium position** is the point about which all the particles oscillate about. It is the dotted line in the diagram above.

The **maximum displacement** from this equilibrium position is called the **amplitude**. It is therefore also half the crest to trough displacement and equal to the crest to equilibrium line distance.

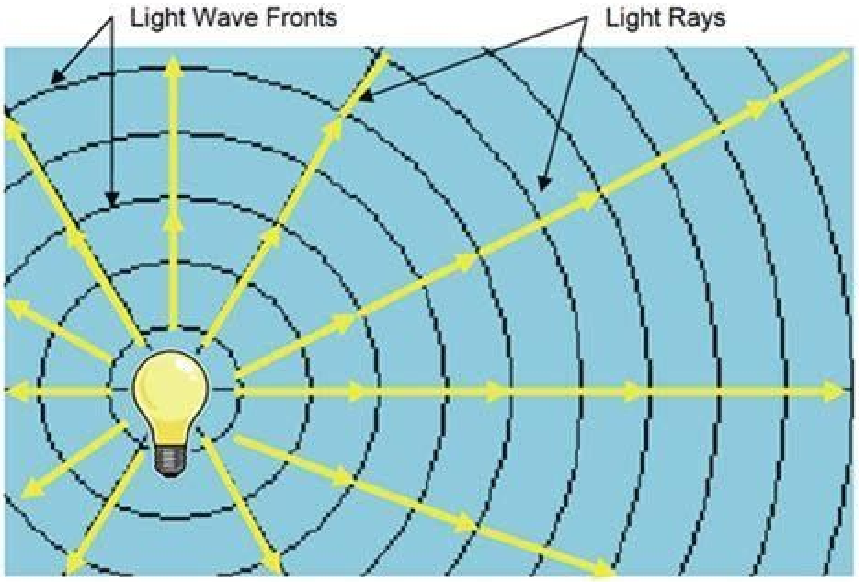
The frequency of a wave is the number of whole waves which pass through a point in a unit time (usually one second). The period of a wave is the time it takes for one of these whole waves to pass through a point. Therefore, $fT = 1$, where f is the wave frequency and T is the wave period.

The velocity of a wave is the speed at which it travels along the direction perpendicular to the particle oscillations. If there are f waves per second and each one is λ metres long (wavelength), then the velocity must be $v = f\lambda$ (metres per second). Often, the velocity is given as the letter v or c.

Graphs

You can see that the **key difference** between these two types of graphs is what the horizontal distance from crest to crest parallel to the x-axis represents. On displacement vs time graphs, this is the time taken for one whole wave to pass a point and so is the **period,** T. However, on displacement vs distance graphs, this is the distance travelled from the start of a wave cycle to its end and hence is the **wavelength** λ.

Wave Fronts



https://www.digikey.com/en/articles/techzone/2011/may/optical-considerations-for-bridgelux-led-arrays

Wave fronts are the lines of **constant phase**. All points on the wave fronts are **in phase**. The wave fronts travel radially from a source and therefore the direction of travel of the waves are along a radial direction (perpendicular to the wave fronts) as shown in the diagram above.