Types of wave:

Transverse:

Here the displacement of particles is perpendicular to the direction of the wave.



Longitidinal:

Here the displacement of particles is in the same plane as (parallel to) the direction of propagation (The direction the wave is moving)





Direction of wave

And the basics for all waves:



(special case $c = f \cdot \lambda$)

Principle of Superposition:

"The displacement of a medium caused by two or more waves is the algebraic sum of the displacement of the waves"

Example – two waves moving towards each other:

Constructive interference:





superposition



Destructive interference:





Nodes and Antinodes:



A **node** is a point on a standing wave where the wave has no amplitude. An **antinode** occurs where the amplitude/displacement/particle movement is greatest

A **standing**, or **stationary**, wave occurs when a wave remains in a constant position usually as a result of interference between two waves traveling in opposite directions for example when the reflected wave interferes with the incident wave on a string. Nodes occur at the fixed ends:



In a **progressive** wave, the wave profile is seen to move (propagate) indicating that energy is being transported in the process. Most familiar waves, light, sound and water (though watch this one), are progressive though it is possible to set up standing waves for each of these. (energy is moved in the form of vibrating particles or fields).



A standing wave on the river in Munich.

Fundamental waves

The 'fundamental' wave is the longest wave that fits, for example on a string. The string must remain stationary at both ends so the modes of vibration are limited to multiples of this number:



Waves in **open** and **closed end tubes** are similar except that the air at an open end of a pipe must be an antinode since there is maximum movement. The air at a closed end must be a node. As a result all harmonics in closed pipes are odd numbers:

Open pipe:



Fundamental (1st Harmonic λ /2)



 2^{nd} Harmonic (λ)



Clarinet

Closed pipe:



Fundamental (1st Harmonic λ /4)



 3^{rd} Harmonic ($3\lambda/4$) (Note all harmonics on closed pipes are odd numbers.)



Bassoon

Polarisation:

Light is composed of a large number of transverse waves pointing in all sorts of directions, up and down, left and right and diagonally – light is normally unpolarised. If you like, each photon emitted from the source is randomly polarised. Polarisation therefore describes the orientation of the oscillation in space.



When light hits a reflective surface it is **slightly** polarised parallel to the surface (not quite like the diagram):



Polarising sunglasses work by <u>reducing</u> the light in the parallel (horizontal on this diagram) direction, thus rebalancing all directions and the reducing glare, which would be the light compressed in the vertical direction in this case.

A polarising filter reduces waves in all directions but one. If two polarising filters are placed perpendicular to each other then no light will get through. The intensity of the light in any particular plane will vary with the angle of the linear polariser



Malus' Law

Consider a stream of completely vertically polarised light (as obtained by passing unpolarised light through the linear polariser seen on the previous diagram with the polarisation axis oriented vertically) of intensity I_0 incident on a sheet of linear polariser with its polarisation axis rotated away from the vertical by an angle θ :



Malus' Law tells us that the intensity *I* of the light transmitted by the rotated polariser depends upon the angle of rotation θ as:

$$I = I_0 \cos^2(\theta) \,.$$

Now, given a beam of light linearly polarised along an unknown axis, we can use a linear polariser and Malus' law to find that axis: simply rotate the polariser to find angle of minimum (or maximum) transmission, and this tells us the axis of the original polarisation.



of polariser angle

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Problem?

If a third polariser (for example an optical isomer or crystal sample) is introduced between two polarisers perpendicular to each other, some light does get through – why?



To understand this, you need to appreciate that a linear polariser does not in fact reduce the photon transmission in any plane, other than that of the polariser, to zero (it reduces it but not to zero). If that were the case then the percentage of light getting through would be very small indeed (around 1%).

If you look at the explanation for Polaroid glasses previously, you will see that the 'glare' from the surface of the water is the result of a horizontal compression.

It is this small remainder of light (or microwaves or any other EM transmission) in the planes slightly offset from the polariser that then go on to pass through the two filter resulting in some light being registered on the far side.

0°

Polarised at zero



Magnitude in each direction reduced

(but not to zero)

