Waves

Waves are the transmission of a disturbance and a method of energy transfer

Mechanical Waves

Require a medium to transfer

Transverse Waves

The medium molecules vibrate **perpendicular** to the direction of energy transfer
e.g. :

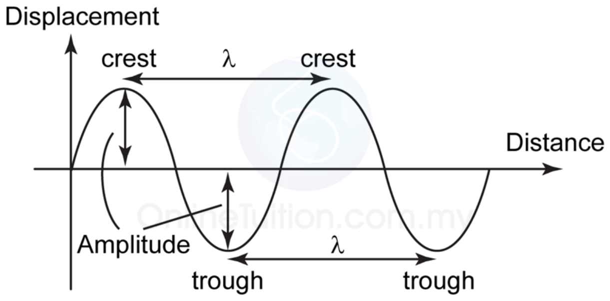
1. Water waves
2. Waves in a rope
3. Any Electromagnetic wave

Longitudinal Waves

The medium molecules vibrate **parallel** to the direction of energy transfer
e.g. :

1. Sound waves

Graphs



- Displacement x Distance
- Displacement x Time

Amplitude (A)

The maximum displacement far from the equilibrium position

- The amplitude reduces overtime due to loss in energy **A.K.A.** Damping
- Measured in m

Wavelength (λ)

The distance between 2 successive points in phase **e.g.** : crests, troughs

- In Displacement x Distance Graph
- Measured in m

Periodic Time (T)

The time taken between 2 successive points in phase **e.g.** : crests, troughs

- In Displacement x Time Graph
  $T = \frac{1}{f}$
- Measured in s

Frequency (f)

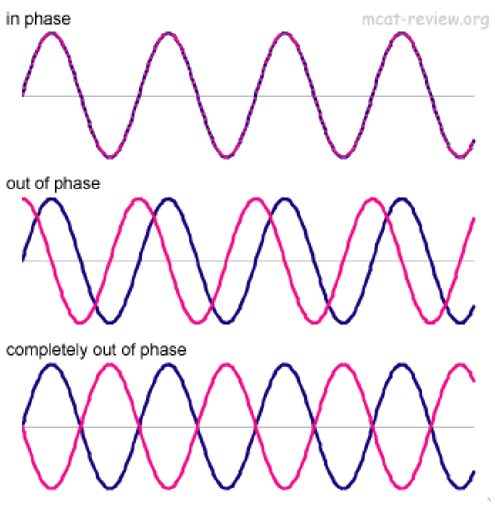
Number of waves per second
$f = \frac{1}{T}$

- Measured in Hz

Phase Shift

The amount by which one oscillation leads or lags behind another.

- Measured in radian



Wave Equation

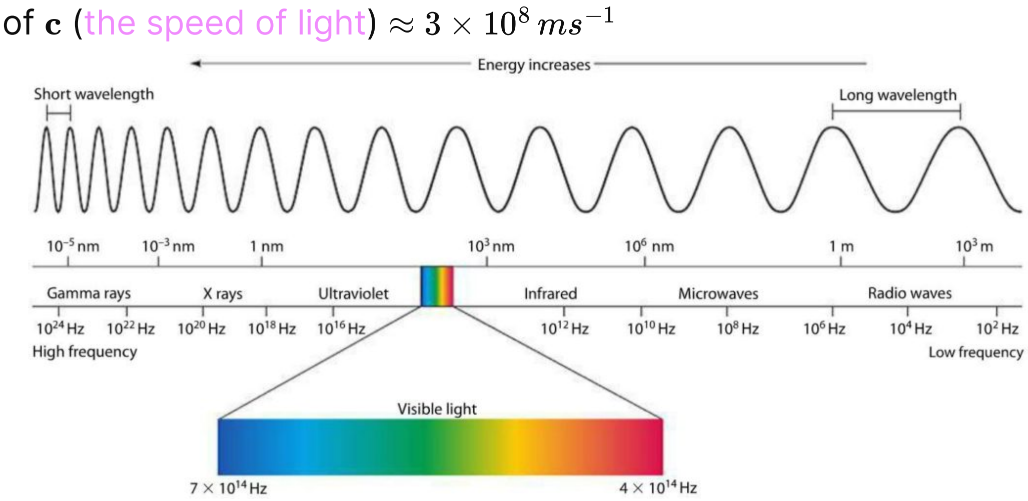
> $v = \frac{d}{t}$
> $v = \frac{\lambda}{T}$
>
> > $$v = \lambda f$$

Electromagnetic Waves

Produced when an oscillating electric or magnetic field creates a self-sustaining oscillation in the electromagnetic field.

As an analogy, consider a swinging pendulum. Energy is constantly being transferred between potential energy and kinetic energy in a swinging mass. But the mass of the pendulum isn't used up and it never has to be replaced (at least, not as a result of the pendulum's operation).

- They come from the interaction between electric and magnetic waves
- Do **not** require a medium to transfer
- They all have a speed of $\mathbf{c}$ (the speed of light) $\approx 3 \times 10^8\, ms^{-1}$



Frequencies						
Gamma Rays	X-Rays	Ultraviolet	Visible Light	Infrared	Microwaves	Radio waves
$10^{24} - 10^{20}$	$10^{20} - 10^{17}$	$10^{17} - 10^{15}$	$10^{15} - 10^{14}$	$10^{14} - 10^{12}$	$10^{12} - 10^{9}$	$10^{9} - 10^{4}$
Wavelengths						
$10^{-16} - 10^{-12}$	$10^{-12} - 10^{-9}$	$10^{-9} - 10^{-7}$	$10^{-7} - 10^{-6}$	$10^{-6} - 10^{-4}$	$10^{-4} - 10^{-1}$	$10^{-1} - 10^{4}$

$\lambda_{violet} = 450\, nm$
$\lambda_{red} = 630\, nm$

Intensity Of Waves

The amount of energy received on a unit area in one second

$$I = \frac{E}{At}$$

- Measured in Wm^{-2}

$I \propto A^2$

- $\mathbf{A}$ → Amplitude of the wave
  $I \propto f^2$
- $\mathbf{f}$ → Frequency of the wave
  $I \propto \frac{1}{r^2}$
- $\mathbf{r}$ → Distance from the source

Doppler Effect

The change of the received frequency of a wave from a moving source

$$f_o = f_s \frac{v}{v \pm v_s}$$

- $\mathbf{f_o}$ → Frequency to the observer
- $\mathbf{f_s}$ → Frequency of the source
- $\mathbf{v}$ → velocity of the wave
- $\mathbf{v_s}$ → velocity of the source
- The Sign in the denominator is "$-$" if the source is approaching and "$+$" if it is receding

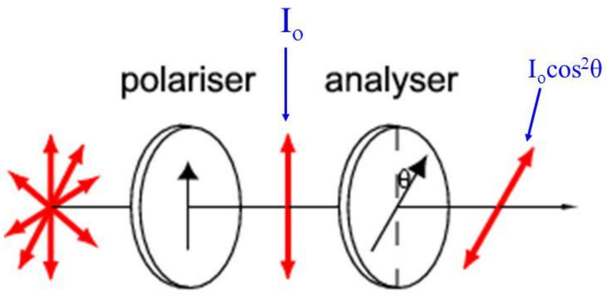
Polarisation of waves

Remark :

- Polarization takes place only with transverse waves

Malus' Law

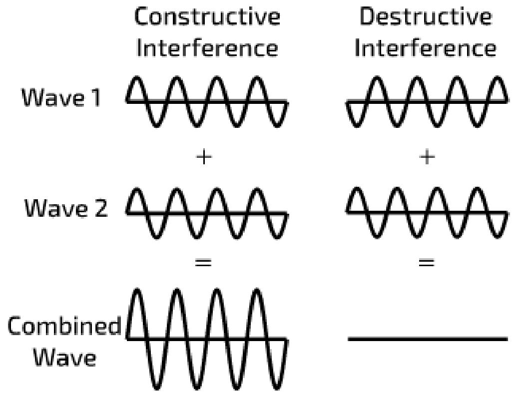
The intensity of polarised light that passes through an analyser varies as the square of the cosine of the angle between the plane of the polariser and the analyser.



$$I = I_0 \cos^2 \theta$$

Superposition

It is the algebraic sum of displacements of 2 or more waves, when they meet at point



Constructive superposition

- occurs when 2 waves are in phase

Destructive superposition

- occurs when 2 waves are completely out of phase

Standing (Stationary) Waves

Waves that don't appear to be moving in the x direction
They are formed due to the superposition of both incident and reflected waves of the same frequency with opposite velocities

Antinode : It's the position of greatest amplitude
Separation : It's the separation between 2 nodes or antinodes
In this GIF, $n = 4$

$$L = n\frac{\lambda}{2}$$

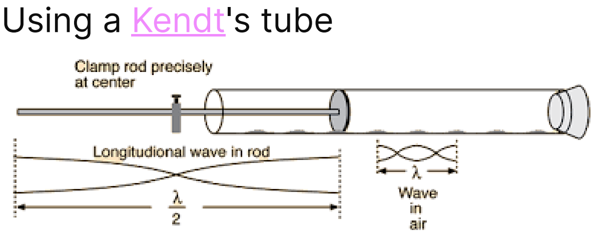
- $\mathbf{L}$ → Length
- $\mathbf{n}$ → Number of standing waves
- λ → Wavelength of the wave

Frequency in standing waves

> $$f \propto n$$
>
> > $$f = f_1 n$$

- $\mathbf{f_1}$ → Fundamental Frequency :- Frequency of one standing wave

Determination of the wavelength of sound

1. With sound waves
    1. emit sound towards a wall where it will form a standing wave
    2. move a microphone connected to a CRO along the direction of the wave
    3. minimum response at anti node
2. Using a Kendt's tube


    1. emit microwaves in a Kendt tube
    2. powder will form heaps at the anti-node
3. Using air columns
    1. glass tube open from both sides
    2. immerse the tube into a beaker filled with water
    3. raise the tube slowly to increase the air column in the tube
    4. bring a hit tuning fork
    5. first loud sound is heard when the wave has an anti-node at the surface of the water

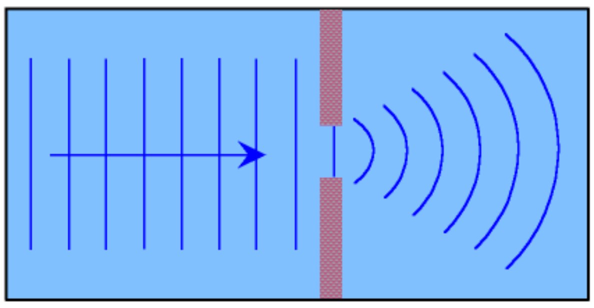
Diffraction

The spreading out of waves when passed through a gap

- Wavelength does not change

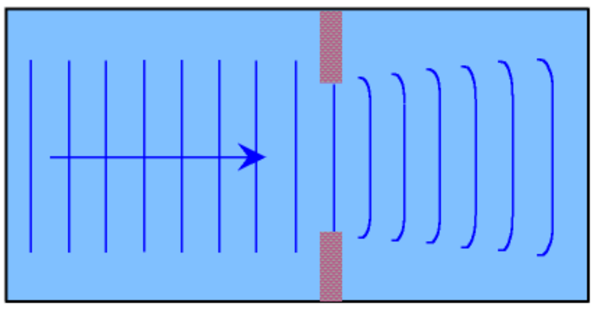
Narrow Gap

Width of the Gap < Wavelength



Wide Gap

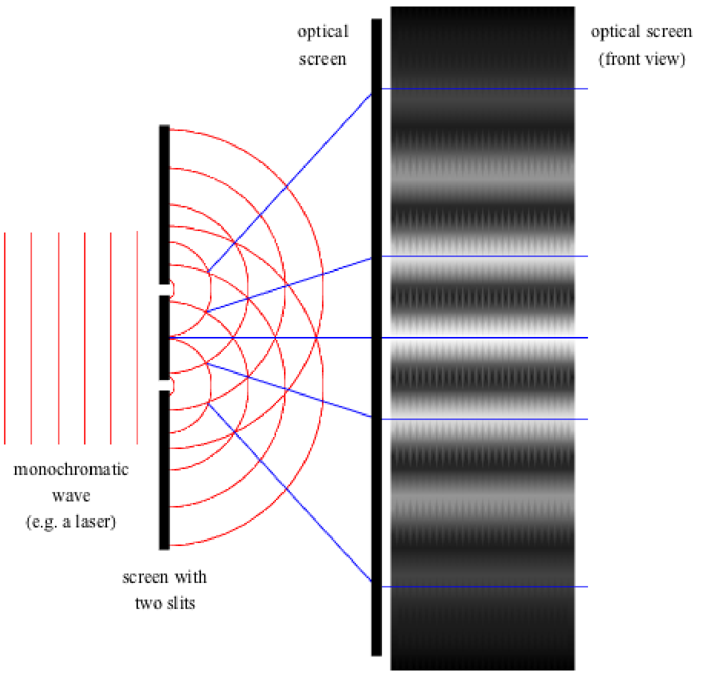
Width of the Gap > Wavelength



- Maximum Diffraction occurs when the Width of the gap is comparable to the Wavelength

Interference of waves

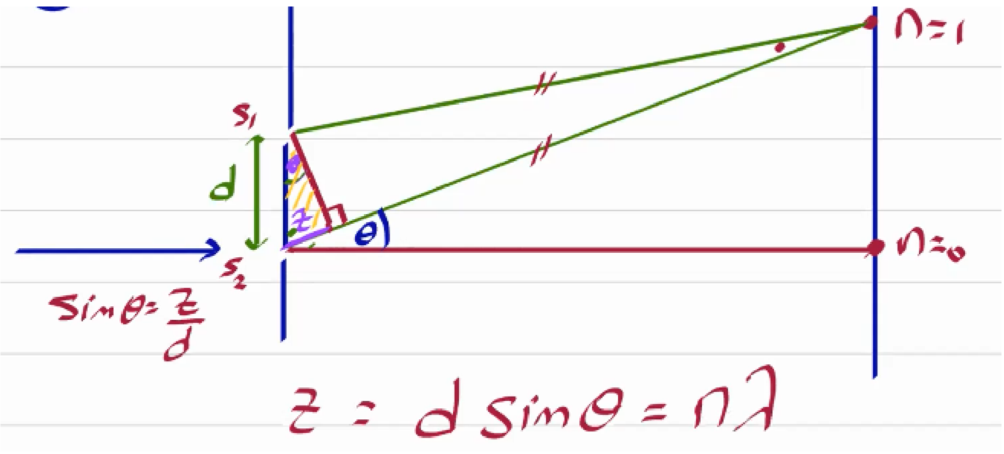
Young's double slit experiment



- Separation between slits should be about 1 mm

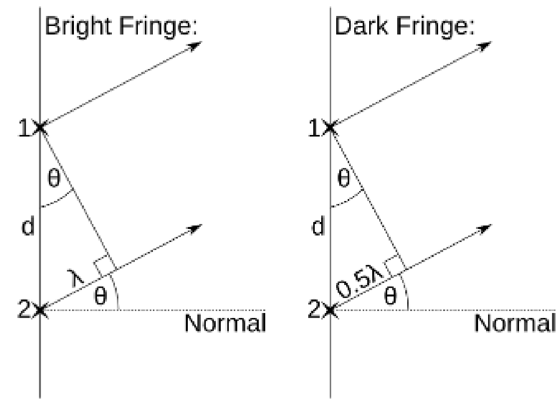
To observe an interference pattern, the 2 sources of waves must be coherent

Coherent Sources : Waves of the same frequency and with constant phase difference relationship



difference between s_1n_1 and s_2n_1 should be one complete wavelength, so that the crests line up and create a bright fringe

$$d\sin\theta = n\lambda$$



- $\mathbf{d}$ → Separation between the 2 slits
- $\mathbf{n}$ → Fringe number on screen

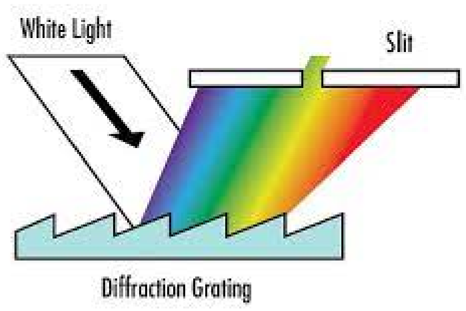
$$\lambda = \frac{ax}{D}$$

- $\mathbf{a}$ → Separation between the 2 slits
- $\mathbf{x}$ → Separation between 2 successive fringes is constant
- $\mathbf{D}$ → Distance between s_2 and n_0

Points to consider when answering questions about interference changes:

1. Brightness of bright fringes
2. Separation between fringes
3. Brightness of the dark positions

Diffraction Grating



Structure that diffracts lights into several beams (sources) traveling in different directions

- Fringes formed have a higher intensity due to several waves taking part in constructively superposition