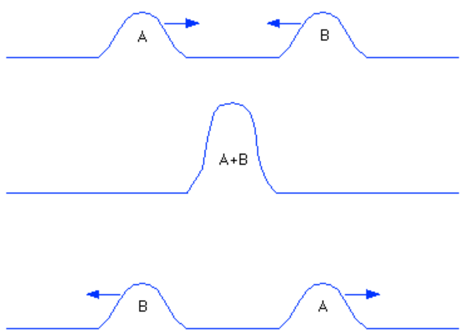
Chapter 8 Superposition

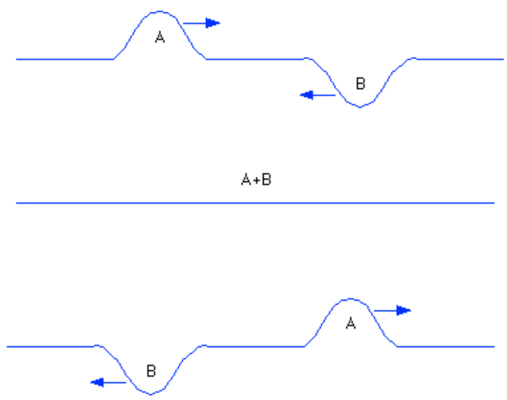
8.1 Stationary waves

Candidates should be able to:	
1	explain and use the principle of superposition
2	show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns (it will be assumed that end corrections are negligible; knowledge of the concept of end corrections is not required)
3	explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes
4	understand how wavelength may be determined from the positions of nodes or antinodes of a stationary wave

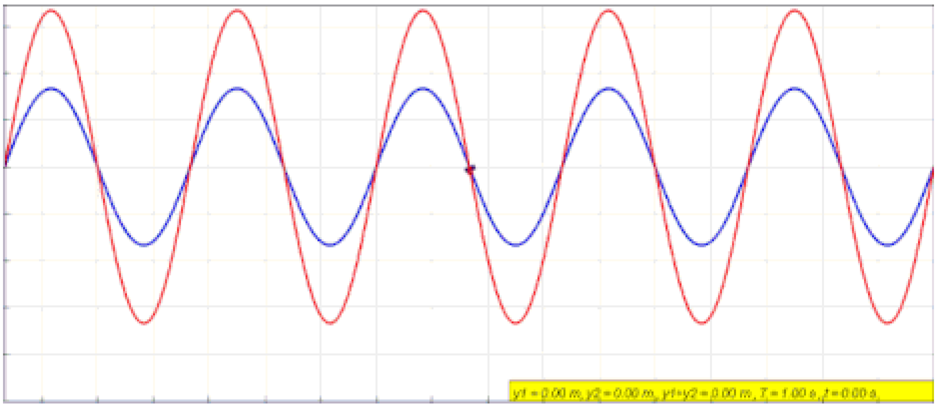
- The **principle of superposition** states then who two opposing waves with the same frequency overlap, the resultant displacement is the sum of the amplitude of each wave.
- **Constructive interference** occurs when the waves are **in phase** and both opposing waves have the **same frequency** and **amplitude**.



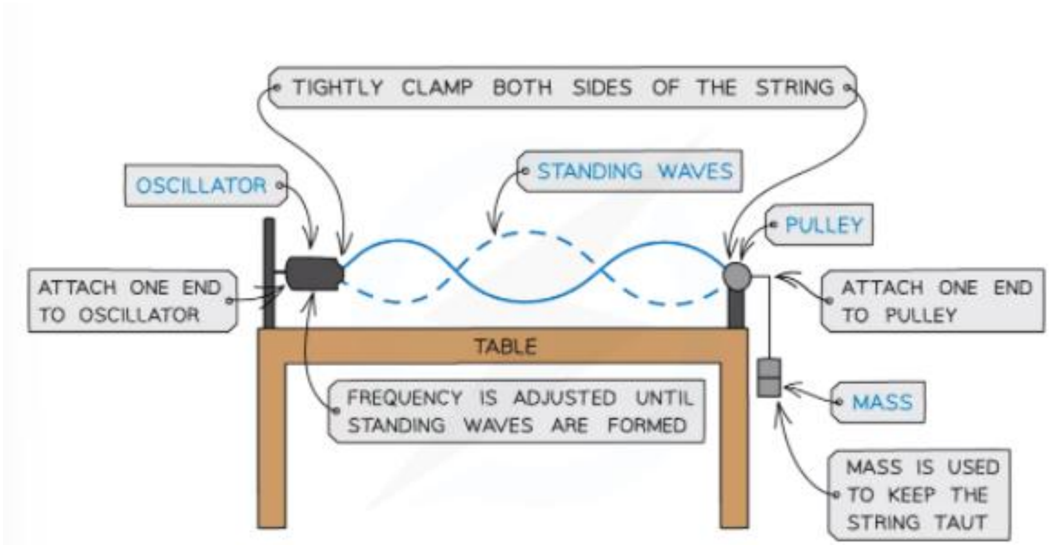
- **Destructive interference** occurs when the waves with the **same frequency** are in **anti-phase** and the peak of one wave coincides with the trough of the other.



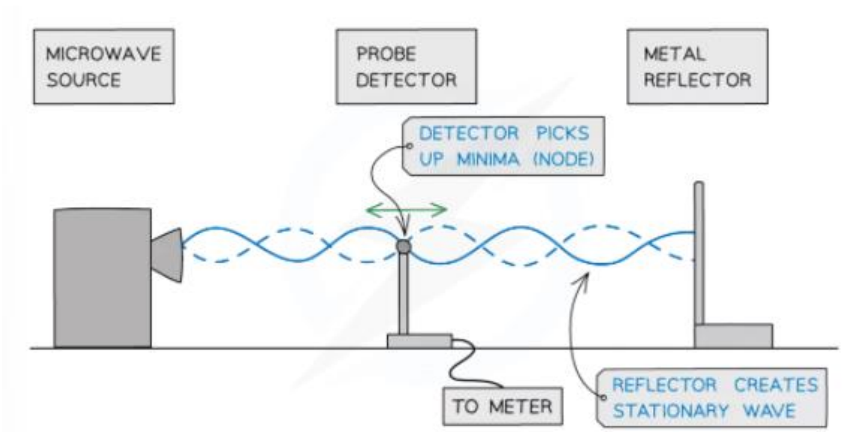
- **Stationary waves** are produced by the **superposition** of two opposing waves of the **same frequency** and **amplitude**.
- Usually produced by a travelling wave and its **reflection**.
- Produces a wave there the **peaks and troughs do not move**.



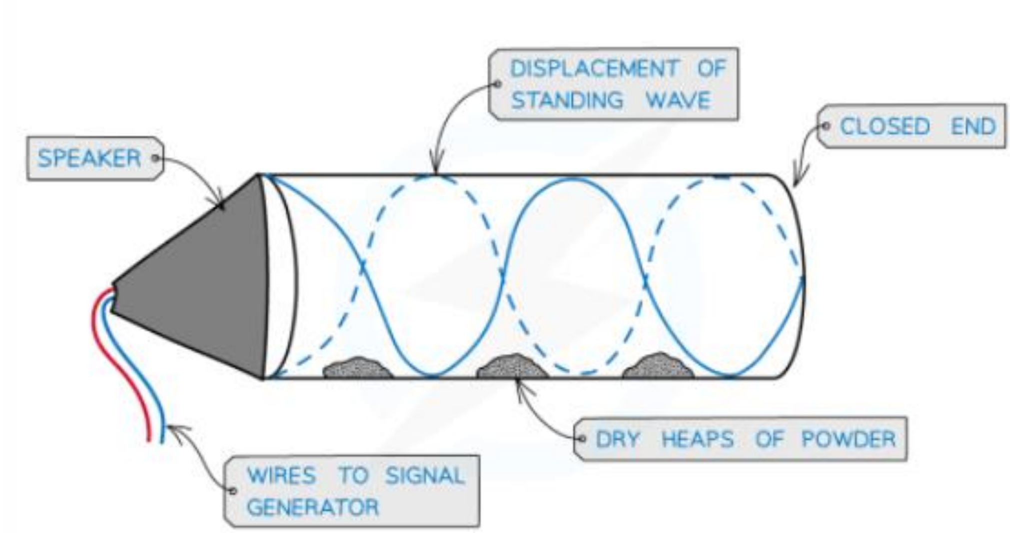
- Vibrations caused by stationary waves on a **stretched string** produce sound waves. E.g. guitars.



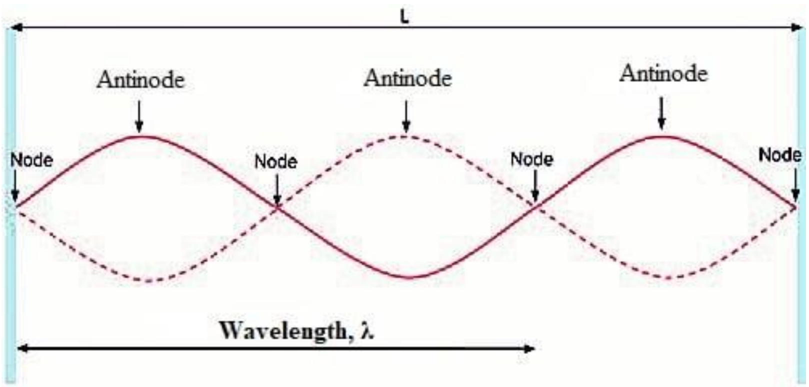
- Standing waves can be created by **microwaves** as well.



- Stationary waves can form inside an **air column** through sound waves. E.g. organs.

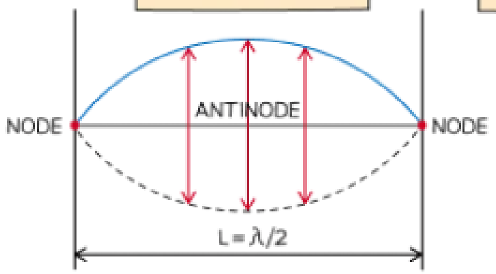


- A stationary wave consists of **nodes** and **antinodes**.
- **Nodes** are where there is **no vibration**.
- **Antinodes** is where amplitude is at a **maximum**.
- Unlike a normal wave antinodes and nodes **do not move** from their position (see gif above)



- Stationary waves have different wave patterns depending on the frequency of the vibration. In AS, you will need to know how to measure the wavelength for **<u>two fixed ends</u>** and one or **<u>two open ends in air column</u>**.

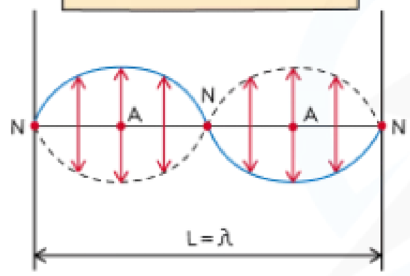
FUNDAMENTAL | **WAVELENGTH λ** | **FREQUENCY = $\frac{c}{\lambda}$**



$\lambda = 2L$

$f = \frac{c}{2L}$

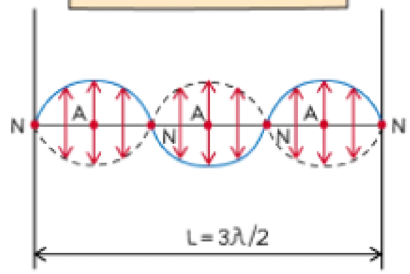
SECOND HARMONIC



$\lambda = L$

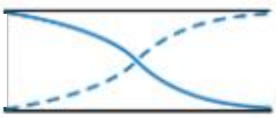
$f = \frac{c}{L}$

THIRD HARMONIC



$\lambda = \frac{2L}{3}$

$f = \frac{3c}{2L}$

Air column fundamental wave	Length L / m	Resonant frequencies f / Hz	Value of n
	$L = \frac{n\lambda}{2}$	$f = \frac{nv}{2L}$	n = 1, 2, 3
	$L = \frac{n\lambda}{4}$	$f = \frac{nv}{4L}$	n = odd
	$L = \frac{n\lambda}{2}$	$f = \frac{nv}{2L}$	n = 1, 2, 3...

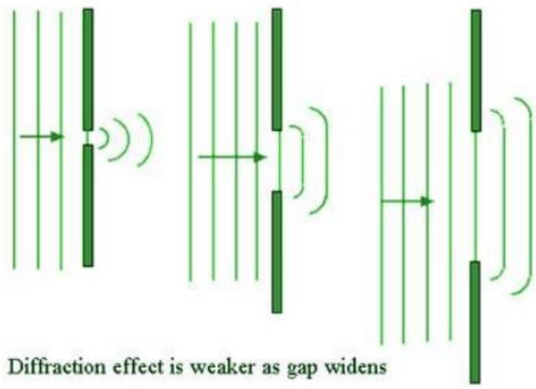
8.2 Diffraction

Candidates should be able to:

1 explain the meaning of the term diffraction

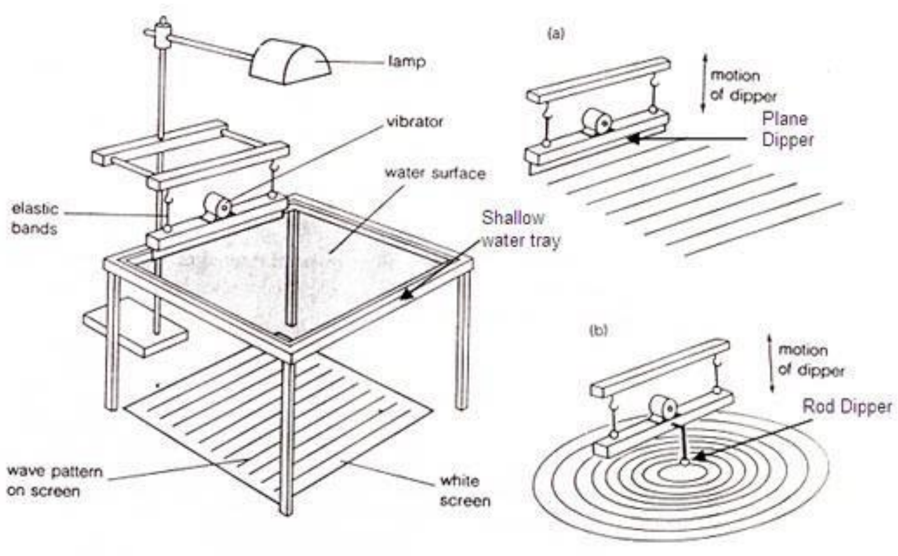
2 show an understanding of experiments that demonstrate diffraction including the qualitative effect of the gap width relative to the wavelength of the wave; for example diffraction of water waves in a ripple tank

- Waves spread out when it passes through an opening or an edge.
- This phenomenon is called **diffraction**.
- Diffraction results in the waves having reduced **amplitude**.
- The extent of diffraction depends on the width of the gap compared with the wavelength of the waves.



Diffraction effect is weaker as gap widens

- Ripple tanks is a common experiment to demonstrate diffraction of water waves

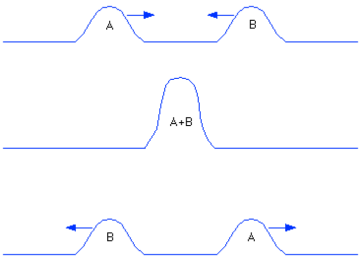


- Here's a good video on Youtube to watch the experiment!
https://www.youtube.com/watch?v=kKne0XydXVU&list=PLkFn4UxH72Z-iRqb1C-6573pthmbU8vwF&index=10&t=2s&ab_channel=kamalWafi

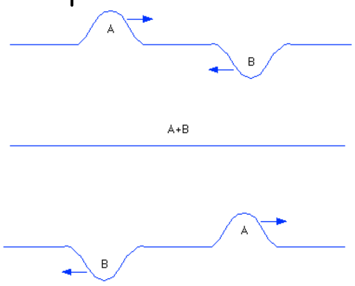
8.3 Interference

Candidates should be able to:	
1	understand the terms interference and coherence
2	show an understanding of experiments that demonstrate two-source interference using water waves in a ripple tank, sound, light and microwaves
3	understand the conditions required if two-source interference fringes are to be observed
4	recall and use $\lambda = ax / D$ for double-slit interference using light

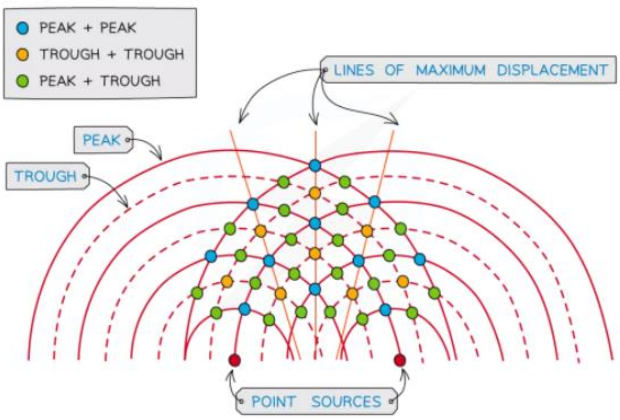
- Interference occurs when waves **overlap** and their resultant displacement is the **sum of the displacement of each wave**.
- Based on the principle of superposition, the resultant waves may be smaller or larger than either two individual waves:
  i) Waves that are in phase causes constructive interference



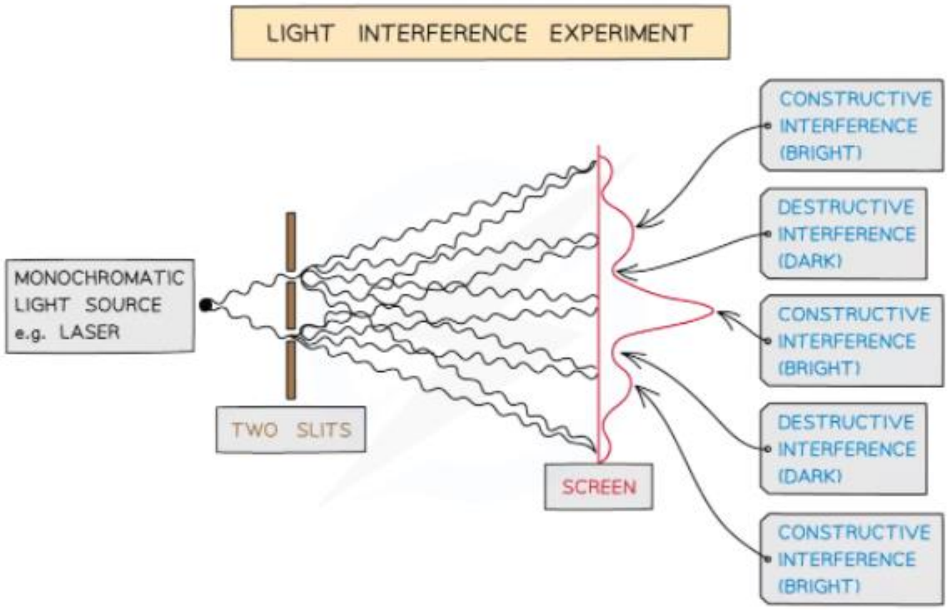
  ii) Waves that are in anti-phase causes destructive interference



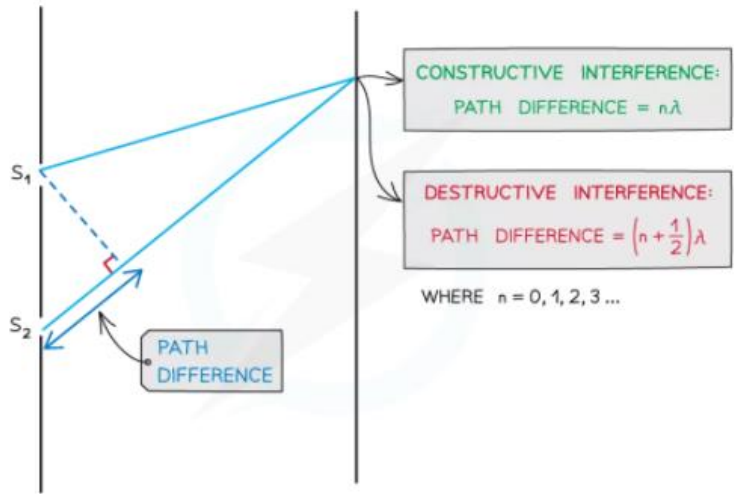
- Waves are coherent if they have the **<u>same frequency</u>** and **<u>constant phase difference</u>**.
- Two-source interference can be demonstrated in water using **<u>ripple tanks</u>**.



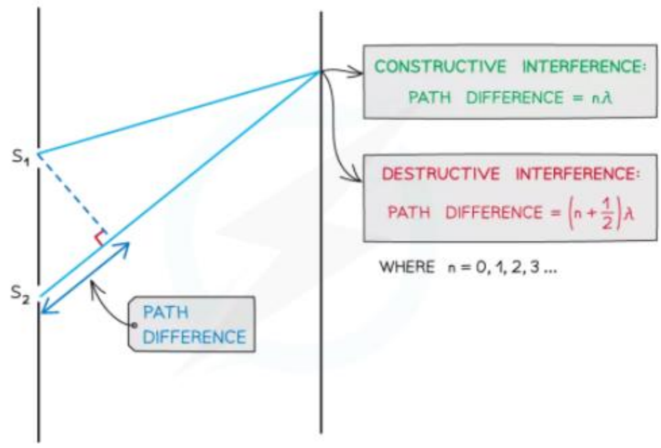
- Laser through **two slits** can also form interference patterns.



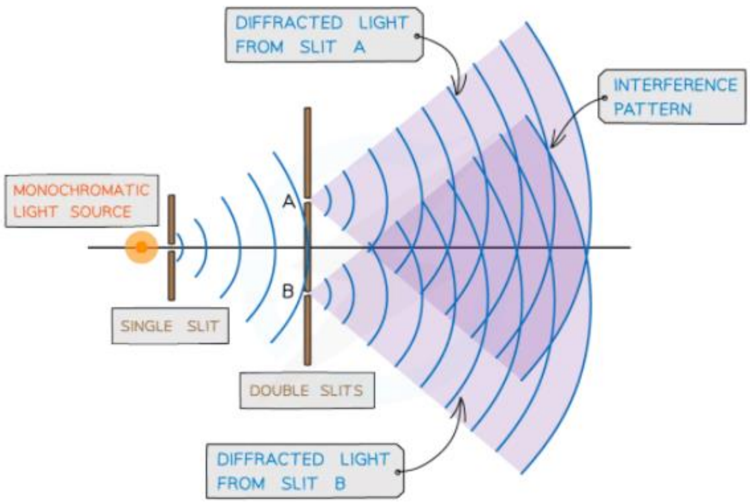
- For two-source interference fringes to be observed, the sources of wave must be **coherent** and **monochromatic** (single wavelength).

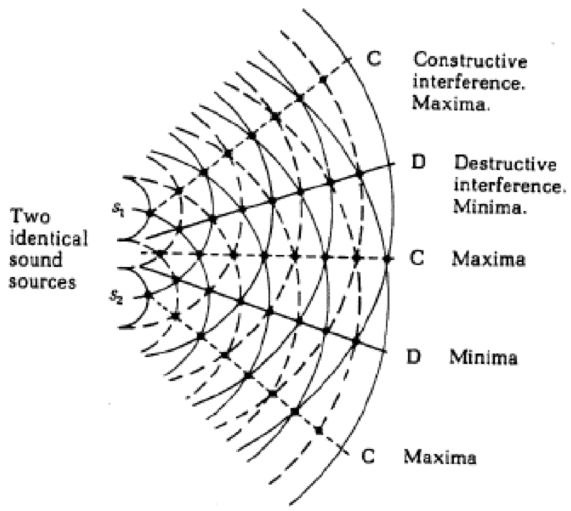


- For **constructive** interference (maxima), the difference in wavelengths will be an **integer number of whole wavelengths**.
- For **destructive** interference (minima) it will be an **integer number of whole wavelengths plus a half wavelength**.



- Young's Double Slit experiment demonstrates how light waves produced an interference pattern.



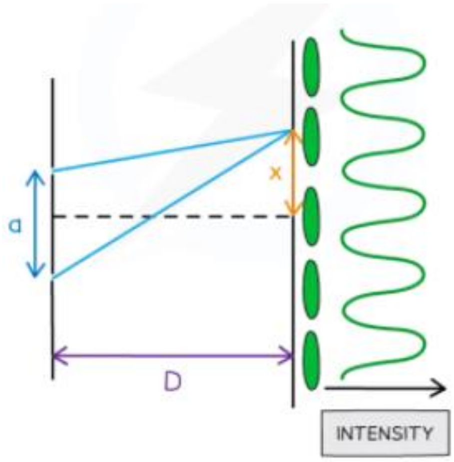


- Since both diffracted light are coherent they will create an observable interference pattern made up of bright (constructive) and dark fringes (destructive).

- The distance between two successive *antinodal* lines or *nodal* lines can be calculated using:

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

- Where *x* is the distance between two successive lines, *a* is distance between two *coherent* sources of waves and *D* is the distance from the waves sources to the line

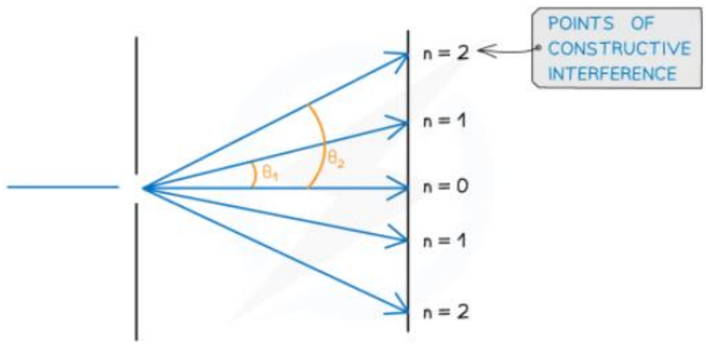


8.4 The diffraction grating

Candidates should be able to:	
1	recall and use $d \sin \theta = n\lambda$
2	describe the use of a diffraction grating to determine the wavelength of light (the structure and use of the spectrometer are not included)

- A diffraction grating is a plate on which there is a very large number of parallel, identical, close-spaced slits.
- The angles at which maxima of intensity are produced, can be deduced by the diffraction grating equation

$$\boldsymbol{d\,sin(\theta) = n\lambda}$$



- The wavelength of light can be determined by rearranging the grating equation

$$\lambda = \frac{d \sin \theta}{n}$$

- We can find θ by using

$$\tan \theta = \frac{h}{D}$$