Superposition

The Principle of Superposition states that when two or more waves of the same kind overlap, the resultant displacement at any point at any instant is the vector sum of the displacements that the individual waves would have separately produced at that point and at that instant.

Interference is the phenomenon which occurs when two or more waves of the same type overlap (superpose) according to the principle of superposition.

Constructive interference occurs when the phase difference is 0 rad and the waves are in phase. The component waves superpose to produce a resultant with a maximum amplitude and intensity.

Destructive interference occurs when the phase difference is π rad and the waves are in antiphase. The component waves superpose with each other to produce a resultant with a minimum amplitude and intensity

		Path Difference	
		$n\lambda$	$\left(n+\frac{1}{2}\right)\lambda$
Sources	**in phase**	Constructive	Destructive
	in antiphase	Destructive	Constructive

Conditions for Observable Interference Pattern

1. The waves must be coherent.
2. The waves should have equal or similar amplitudes.
3. For transverse waves, they must either be unpolarised, or polarised in the same plane.

Diffraction refers to the spreading of waves when they travel through a small opening or when they pass round a small obstacle.

Diffraction appears most significant when the size of the aperture (or obstacle) is of the same order of magnitude as the wavelength of the wave.

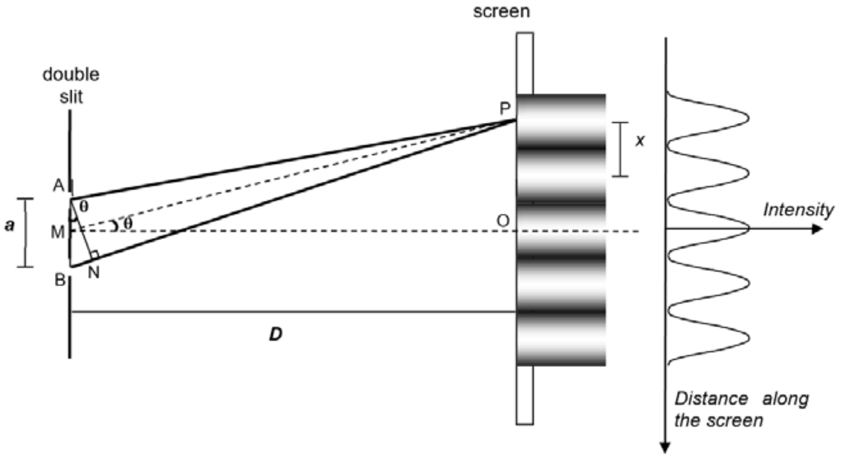
Young's Double Slit Experiment

The fringe separation (distance between successive bright fringes) x is given by the equation

$$x = \frac{\lambda D}{a}$$

where λ is the wavelength of the light,
D is the distance from the double slits to the screen,
a is the separation of the two slits (measure from centre to centre of slits)

Note: This formula is only valid when D is much larger than a ($D >> a$).

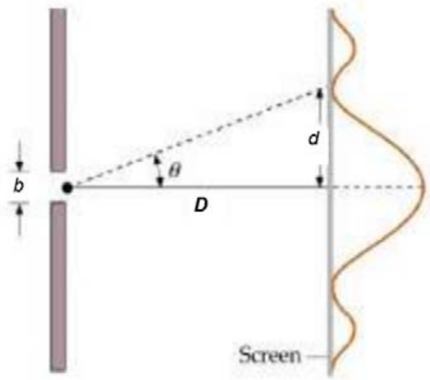


Single-slit Diffraction

The angle θ at which the first minima occurs using the relationship

$$\sin\theta = \frac{\lambda}{b}$$

where λ is the wavelength of the light,
b is the width of the single slit.



Rayleigh's criterion

When the central maximum of one image falls on the first minimum of another image, the images are distinguishable and said to be just resolved. This limiting condition of resolution is known as Rayleigh's criterion.

Mathematically, Rayleigh's criterion is expressed as

$$\theta_{\text{min}} \approx \frac{\lambda}{b}$$

where θ is the limiting angle of resolution,
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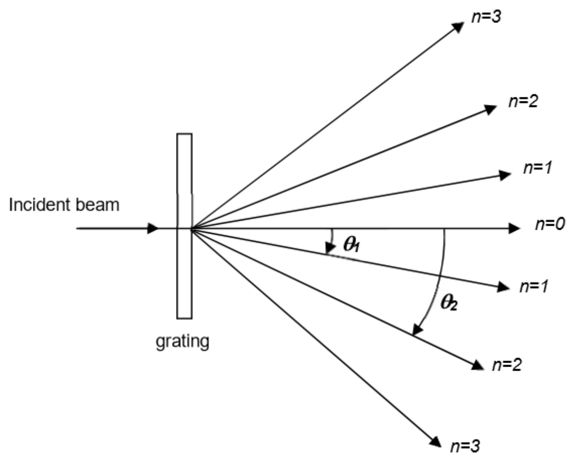
Diffraction Grating

The position (or angle) of the n^{th} order intensity maximum may be determined using:

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

where d = line spacing (i.e. slit separation) of the diffraction grating
n = order of diffraction, an integer
θ = angle between the n^{th} order beam and the normal to the grating
λ = wavelength of the incident beam

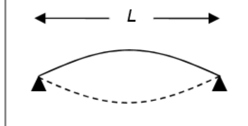
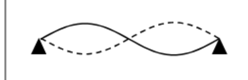


Stationary Waves

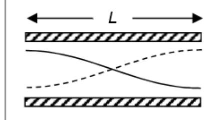
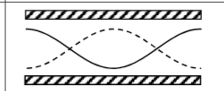
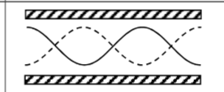
A stationary wave is the result of interference

- between two identical waves (same amplitude, frequency);
- travelling along the same line with the same speeds;
- but in opposite directions.

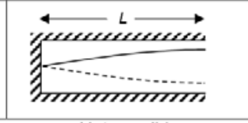
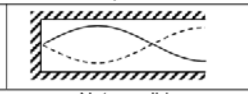
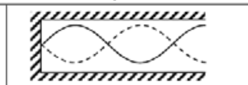
Stationary (Transverse) Wave on a Stretched String (2 fixed ends)

Harmonic series	Overtone	Mode of vibration	Wavelength	Frequency
1			$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$ fundamental
2	1		$\lambda_2 = L$	$f_2 = \frac{v}{L}$
3	2		$\lambda_3 = \frac{2L}{3}$	$f_3 = \frac{3v}{2L}$
n	n-1	All harmonics possible	$\lambda_n = \frac{2L}{n}$	$f_n = \frac{nv}{2L}$

Stationary (Sound) Wave within an Open Pipe (2 ends open)

Harmonic series	Overtone	Mode of vibration	Wavelength	Frequency
1			$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$ fundamental
2	1		$\lambda_2 = L$	$f_2 = \frac{v}{L}$
3	2		$\lambda_3 = \frac{2L}{3}$	$f_3 = \frac{3v}{2L}$
n	n-1	All harmonics possible	$\lambda_n = \frac{2L}{n}$	$f_n = \frac{n\,v}{2\,L}$

Stationary (Sound) Wave within a Closed Pipe (one end open, one end closed)

Harmonic series	Overtone	Mode of vibration	Wavelength	Frequency
1			$\lambda_1 = 4L$	$f_1 = \frac{v}{4L}$ fundamental
2	Not possible			
3	1		$\lambda_2 = \frac{4L}{3}$	$f_2 = \frac{3v}{4L}$
4	Not possible			
5	2		$\lambda_3 = \frac{4L}{5}$	$f_3 = \frac{5v}{4L}$
n		Only odd-numbered harmonics are possible	$\lambda_n = \frac{4L}{n}$	$f_n = \frac{nv}{4L}$

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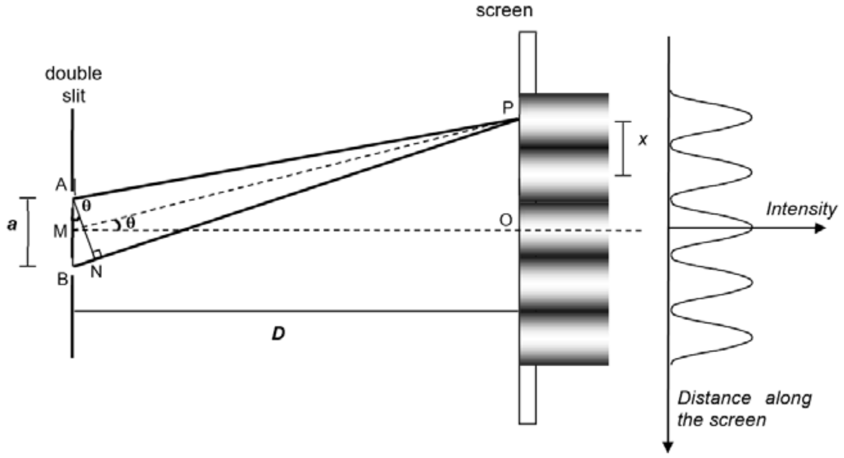

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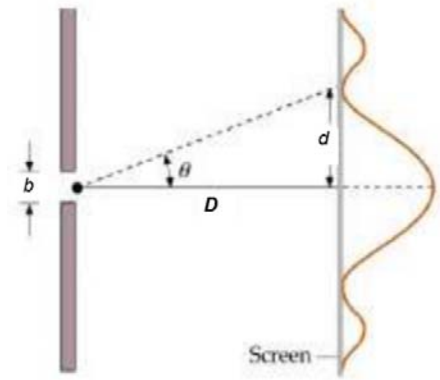

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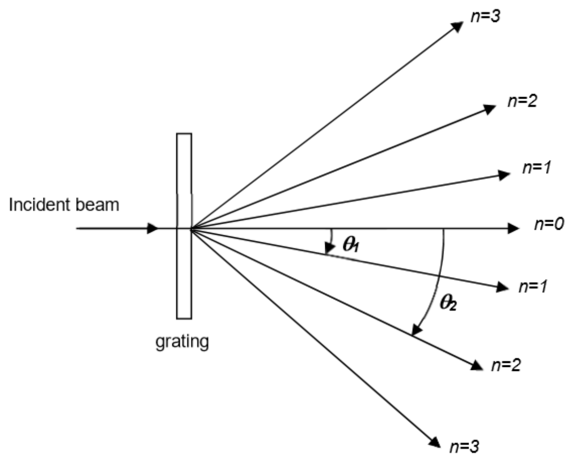

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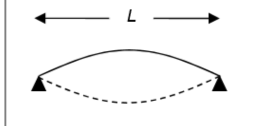
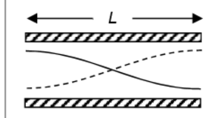
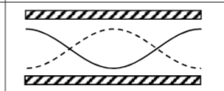
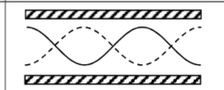
1			$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$ fundamental
2	1		$\lambda_2 = L$	$f_2 = \frac{v}{L}$
3	2		$\lambda_3 = \frac{2L}{3}$	$f_3 = \frac{3v}{2L}$
n	n-1	All harmonics possible	$\lambda_n = \frac{2L}{n}$	$f_n = \frac{nv}{2L}$

Stationary (Sound) Wave within an Open Pipe (2 ends open)

Harmonic series	Overtone	Mode of vibration	Wavelength	Frequency
1			$\lambda_1 = 2L$	$f_1 = \frac{v}{2L}$ fundamental
2	1		$\lambda_2 = L$	$f_2 = \frac{v}{L}$
3	2		$\lambda_3 = \frac{2L}{3}$	$f_3 = \frac{3v}{2L}$
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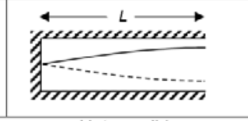
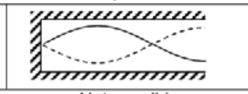
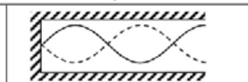
Stationary (Sound) Wave within a Closed Pipe (one end open, one end closed)

Harmonic series	Overtone	Mode of vibration	Wavelength	Frequency
1			$\lambda_1 = 4L$	$f_1 = \frac{v}{4L}$ fundamental
2	Not possible			
3	1		$\lambda_2 = \frac{4L}{3}$	$f_2 = \frac{3v}{4L}$
4	Not possible			
5	2		$\lambda_3 = \frac{4L}{5}$	$f_3 = \frac{5v}{4L}$
n		Only odd-numbered harmonics are possible	$\lambda_n = \frac{4L}{n}$	$f_n = \frac{nv}{4L}$