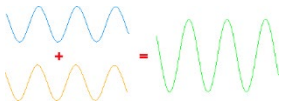
Interference

Definitions

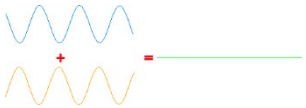
Interference

When waves run into each other, they usually don't reflect. Instead, they combine. Constructive interference will make a sound louder/brighter light while destructive interference will make a sound quieter/dimmer light.

When two waves of the same wavelength and frequency occur in the same place, they will have an effect on each other. If two waves are in sync, (the crest from one wave coincides with the crest from the other), they add up: this is a constructive interference.

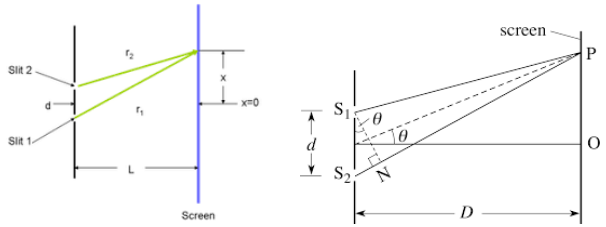


If two waves are half a wavelength out of sync (the crests from one wave coincides with the troughs from the other), they cancel out, and the resulting wave will be zero; this is a destructive interference.



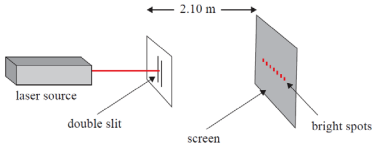
Equations/Diagrams

$d\sin\theta = n\lambda$	Slit separation	d	m
	Angle from original direction of beam	θ	°
	The order of interference (1,2,3,..)	n	-
	wavelength	λ	m
$n\lambda = \frac{dx}{L}$	The order of interference (1,2,3,..)	n	-
	wavelength	λ	m
	Slit separation	d	m
	Displacement from original direction of beam	x	
	Distance from grating to screen	L	m
$v = f\lambda$	Velocity of wave	v	m s^{-1}
	frequency	f	Hz
	wavelength	λ	m
$f = \frac{1}{T}$	Frequency	f	Hz
	Time period	T	s



Questions

DIFFRACTION GRATINGS (2016;3)



Moana is doing an experiment in the laboratory. She shines a laser beam at a double slit and observes an interference pattern on a screen. The diagram below shows the experiment. Moana measures the distance between adjacent bright spots (maxima) and finds they are 0.0100 m apart. The slits are 1.28 x 10^{-4} m apart. The screen is 2.10 m from the slits.

(a) Show that the wavelength of the laser light is 6.10 x 10^{-7} m.

(b) Moana replaces the double slit with a diffraction grating in the same position. The diffraction grating has 500 lines per mm. Calculate the angle between the central antinodal line and the first antinodal line.

(c) Explain what would happen to the distance between the bright spots on the screen if the laser source is changed to one with a shorter wavelength.

(d) Moana shines white light through a diffraction grating. The pattern she sees is shown. Explain the pattern Moana observes. Your explanation should include:

- why the centre of the pattern is white
- why there is a coloured spectrum on each side
- why there are dark regions between the white and coloured regions.

Terms

Antinodal lines: Lines of constructive interference
Bright fringe: Area of constructive interference
Constructive interference: Two waves arriving at the same place, at the same time and in phase, add to create a wave with a larger amplitude
Dark fringe: Area of destructive interference
Destructive interference: Two waves arriving at the same point at the same time out of phase add their amplitudes to create zero total disturbance
Intensity: A measure of the energy carried by a wave
Interference: Effect occurring when waves meet
Loudness: Related directly to the amount of energy of the vibrating source
Nodal lines: Lines of destructive interference
Slit: Gap /Aperture
Superimposed: When two or more waves occupy the same position at the same time, they 'overlap' and show a combined pattern

Tips

θ is the angle between the light rays and a line drawn from a slit perpendicular to the screen.
x is the distance measured from a point on the screen opposite the center of the slits, and the point where the two rays meet. If $x << L$, then $\sin\theta \approx x/L$.

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

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

Constructive interference will occur when the path difference, $d \sin \theta$, is equal to a whole number of wavelengths. n = 0, 1, 2, 3, ...

Destructive interference (dark bands) will occur when the path difference, is equal to an odd number of half-wavelengths. n = 1/2, 3/2, 5/2, 7/2.

Answers

(a)
$$n\lambda = \frac{dx}{l}$$
$$\lambda = \frac{1.28\times10^{-4}\times0.0100}{2.10}$$
$$\lambda = 6.10\times10^{-7}\ \text{m}$$

(b)
$$500\ \text{lines mm}^{-1} = 5\times10^{5}\ 1\text{m}^{-1}$$
$$d = \frac{1}{5\times10^{5}} = 2\times10^{-6}\ \text{m}$$
$$\sin\theta = \frac{n\lambda}{d} = \frac{6.10\times10^{-7}}{2\times10^{-6}} = 0.305$$
$$\theta = 17.5°$$

(c) $\sin\theta = \frac{n\lambda}{d}$ if wavelength decreases and d is constant, $\sin\theta$ will decrease (so θ will decrease) so antinodes / bright spots get closer.

(d) White seen is central antinode. Different colours have 1st antinode at different angle. Dark regions are nodes (to destructive interference).