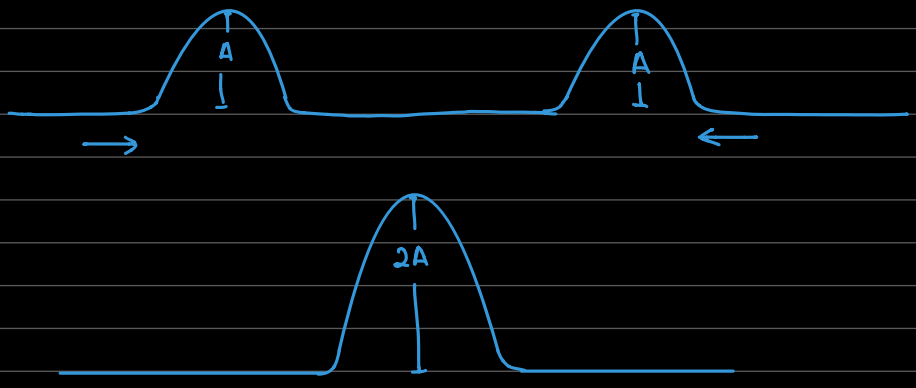
SUPERPOSITION : WAVES

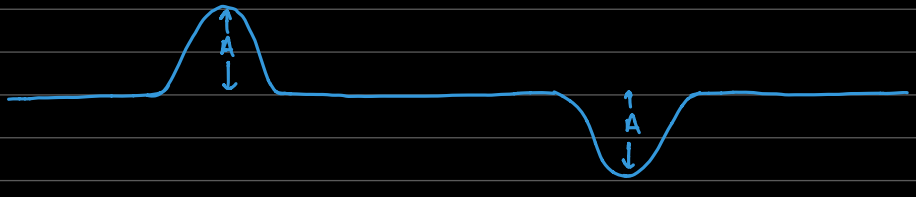
- According to the Principle of Superposition, if two or more waves overlap/meet at a common point, then the total displacement due to these waves will be the sum of their individual displacements

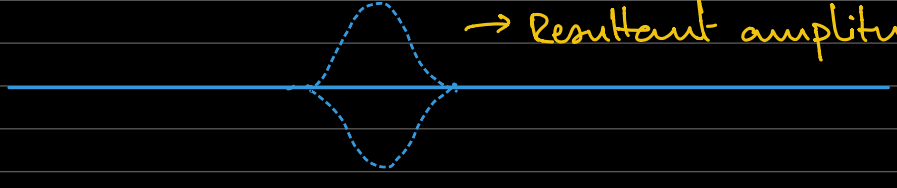


- The phenomena of superposition gives rise to interference
- The above case can be classified by the term "constructive interference"
- Constructive interference occurs when in-phase points superimpose each other
- For constructive interference to occur, we can say that the path difference will be 1λ, 2λ, 3λ ... etc.
  ↳ and phase difference will be 2π, 4π, 6π ... etc.

Destructive Interference:

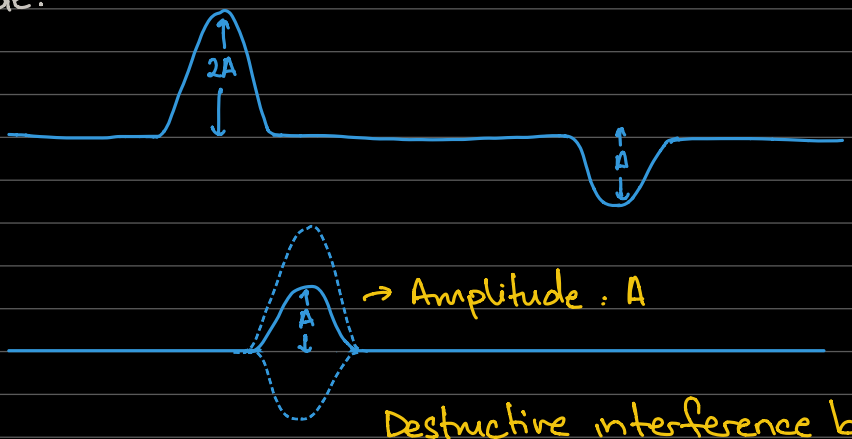
- Think of a crest with amplitude A overlapping a trough also with amplitude A.





→ Resultant amplitude = 0, hence <u>destructive</u> interference

Example:



Destructive interference because amplitude decreases by A

- For destructive interference, the path corresponds to $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$ ... $\frac{n}{2}\lambda$ where n is an odd integer

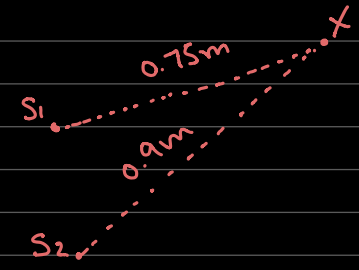
and the phase difference corresponds to π, 3π, 5π ... $n\pi$ where n is an odd integer

Example: Two sources of microwaves

$v = 3 \times 10^8$ m/s

$f = 12$ GHz

Determine what type of interference will occur when waves from S_1 and S_2 meet at a point x.



$S_1X = 0.75$m

$S_2X = 0.9$m

1st method:

$v = f\lambda$

$3 \times 10^8 = (12 \times 10^9)\lambda$

$\lambda = 0.025$m

① How many waves will be formed along the path S_1X?

$\frac{0.75}{0.025}$ = 30 waves or 30λ

② How many waves will be formed along the path S_2X?

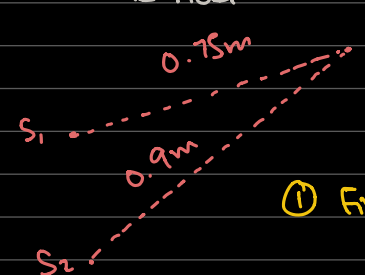
$\frac{0.9}{0.025}$ = 36 waves of 36λ

③ Path difference = $36\lambda - 30\lambda$

$= 6\lambda$

∴, they meet in-phase at x and hence, constructive interference occurs (the amplitude increases / doubles)

2nd method



$v = f\lambda$

$3 \times 10^8 = (12 \times 10^9)\lambda$

$\lambda = 0.025$

① First calculate the path difference between S_1X and S_2X

$= 0.9 - 0.75$

$= 0.15\,m$

② Then determine how many waves can be formed in this path difference of 0.15 m.

$\frac{0.15}{0.025} = 6$ waves or 6λ

Note: Method #2 can only be used when the wavelengths of the colliding waves is the same

∴, since meeting waves are in-phase, constructive interference occurs

CONDITIONS REQUIRED FOR INTERFERENCE TO OCCUR:

General

- Waves must meet at a common point
- Waves must be of the same type and medium
- Waves must travel in the same plane
- Waves must be <u>coherent</u> (means that the path difference and phase difference between the two waves must remain constant).

Constructive Interference

- The two waves must meet in-phase with each other

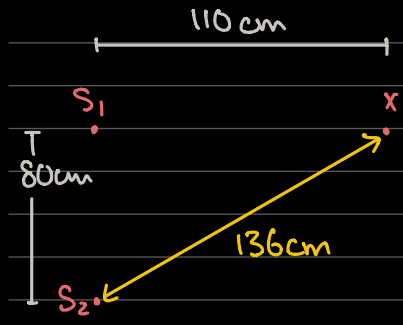
Destructive Interference

- The two waves must meet out-of-phase with each other

Example:

The diagram shows S_1 and S_2. The waves produced meet at X. It is given that the frequency of both sources is simultaneously varied from 1000 Hz until it reaches 4000 Hz. The speed of the waves is 340 ms^{-1}

Calculate on how many occasions would you expect the phenomena of <u>destructive</u> interference to occur at the point X.



When $f = 1000\,Hz$

$v = f\lambda$

$340 = 1000\lambda$

$0.34m = \lambda$

$34cm = \lambda$

When $f = 4000\,Hz$

$v = f\lambda$

$340 = 4000\lambda$

$0.085 = \lambda$

$8.5cm = \lambda$

Hence, $8.5cm \leq \lambda \leq 34cm$

For destructive interference to occur, path difference must be $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$, $\frac{7}{2}\lambda$ .... etc.

Waves from S_2 travel 136cm to get to x, while waves from S_1 travel 110cm.

Therefore, for destructive interference to occur, the phase difference (136 - 110 = 26cm in this case) must be equal to odd multiples of $\frac{1}{2}\lambda$

$26 = (1)(\frac{1}{2}\lambda)$	$26 = (3)(\frac{1}{2}\lambda)$	$26 = (5)(\frac{1}{2}\lambda)$	$26 = (7)(\frac{1}{2}\lambda)$	$26 = (9)(\frac{1}{2}\lambda)$
$26 = \frac{1}{2}\lambda$	$26 = \frac{3}{2}\lambda$	$26 = \frac{5}{2}\lambda$	$26 = \frac{7}{2}\lambda$	$26 = \frac{9}{2}\lambda$
$52cm = \lambda$	$17.3cm = \lambda$	$10.4cm = \lambda$	$7.4cm = \lambda$	$5.7cm = \lambda$

λ is too large for the range

λ is perfectly in the earlier range we calculated on 2 occasions

λ decreases beyond the range

$$8.5cm \leq \lambda \leq 34cm$$

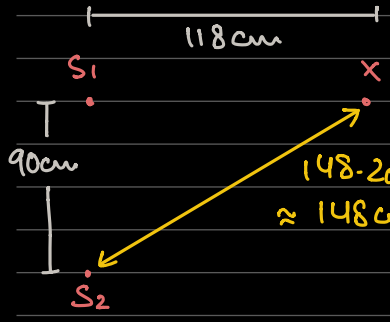
Ans → ∴, destructive interference will occur on 2 occasions

Example:

$f = 500\,Hz \longrightarrow f = 4500\,Hz$

$v = 340\,ms^{-1}$

Determine on how many occasions constructive interference will occur.



For $f = 500\,Hz$

$v = f\lambda$

$340 = 500\lambda$

$0.68 = \lambda$

$68cm = \lambda$

For $f = 4500\,Hz$

$v = f\lambda$

$340 = 4500\lambda$

$0.076\,m = \lambda$

$7.6cm = \lambda$

∴, $7.6cm \leq \lambda \leq 68cm$

For constructive interference to occur, the path difference must be λ, 2λ, 3λ ... (ie. an integer multiple of λ)

$148 - 118 = 30\,cm$

$30 = (1)\lambda$	$30 = (2)\lambda$	$30 = (3)\lambda$	$30 = (4)\lambda$	$30 = (5)\lambda$	$30 = (6)\lambda$
	$\frac{30}{2} = \lambda$	$\frac{30}{3} = \lambda$	$\frac{30}{4} = \lambda$	$\frac{30}{5} = \lambda$	$\frac{30}{6} = \lambda$
$30\,cm = \lambda$	$15cm = \lambda$	$10\,cm = \lambda$	$7.5cm = \lambda$	$6cm = \lambda$	$5cm = \lambda$

these 3 values of λ are in range → λ decreases beyond the range

$$\boxed{7.6 \leq \lambda \leq 68}$$

Ans → ∴, constructive interference will occur on 3 occasions