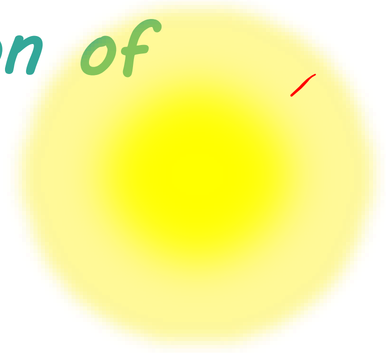
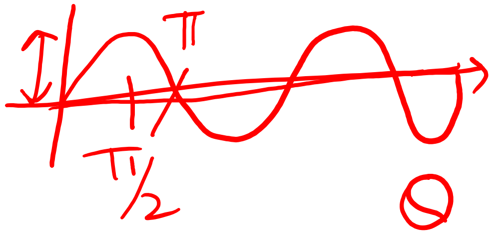
Some Background about Light

- Light has dual nature: wave nature and particle nature
- When we talk about interference, we deal with wave nature of light
- According to wave theory, the light emitted from a source travels in the medium (or in vacuum) in the form of waves, and spreads in all directions.
- When there is a single source of light, the distribution of light energy is uniform in space.

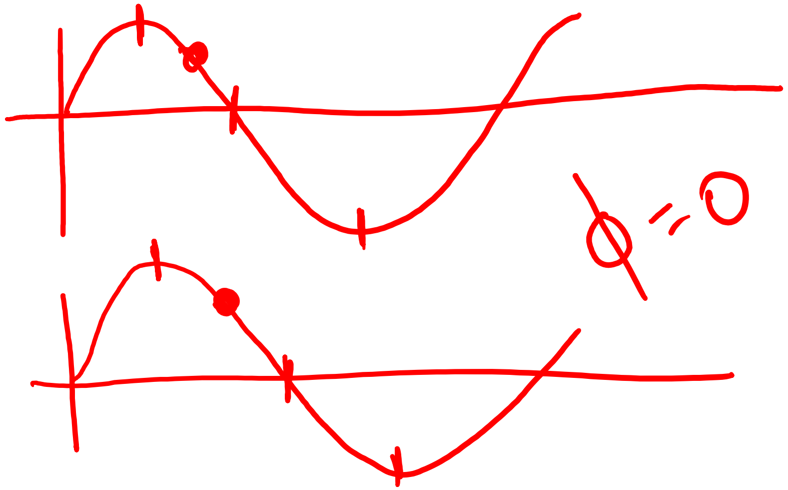


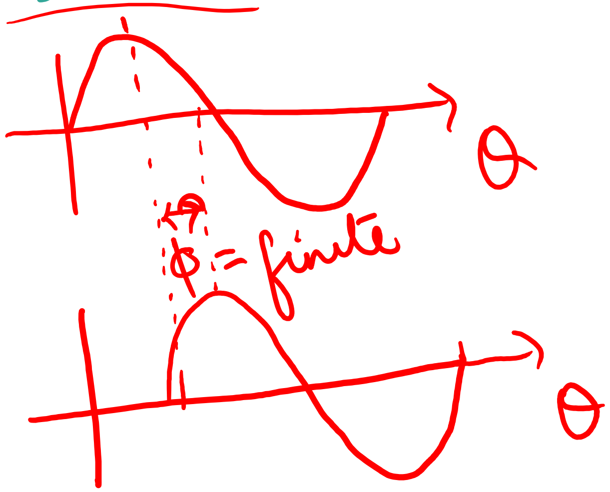
Wave, phase and difference

- A wave in simplest form is described by a sine function.



- The phase refers to the angle θ on the x-axis.



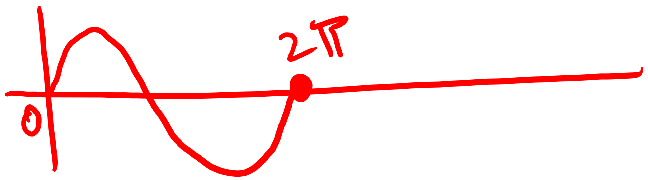


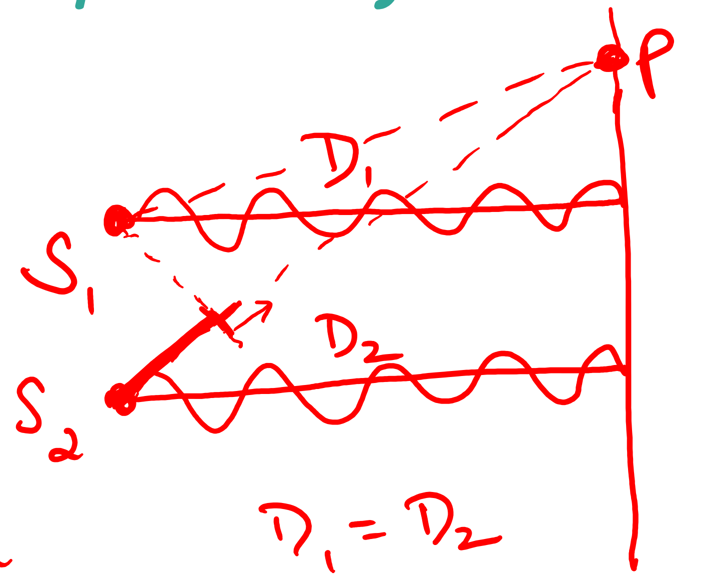
- When we consider two waves, the difference in their position represents the phase difference, ϕ

Phase difference and path difference

ϕ Δ

- Phase difference is defined as the difference in the phase angles of two vibrating particles or waves.





$S_1P \neq S_2P$

$S_2P - S_1P = \Delta$

$D_1 = D_2$

$\Delta = D_2 - D_1 = 0$

When $\Delta = \lambda$

then $\phi = 2\pi$

$\frac{\phi}{\Delta} = \frac{2\pi}{\lambda} \Rightarrow$

Vacuum

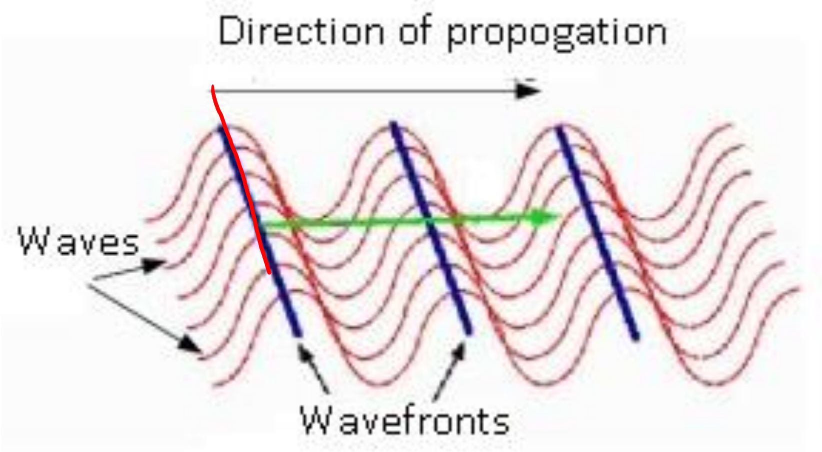
$$\boxed{\phi = \frac{2\pi}{\lambda} \cdot \Delta}$$

For medium, μ

$$\boxed{\phi = \frac{2\pi}{\lambda} \mu \Delta}$$

Wavefront

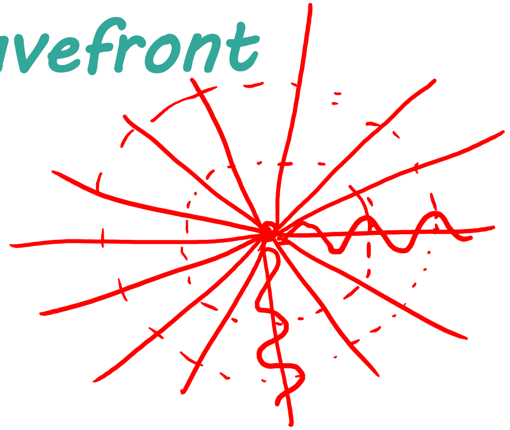
In optics, a wavefront is a locus of points over which a wave has constant phase. The locus of points makes a surface.



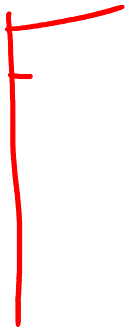
The direction of propagation of wave is perpendicular to the surface of wavefront.

Types of wavefront

Point source ⟶ spherical wavefront



Line source ⟶ cylindrical wavefront



Plane source ⟶ plane wavefront

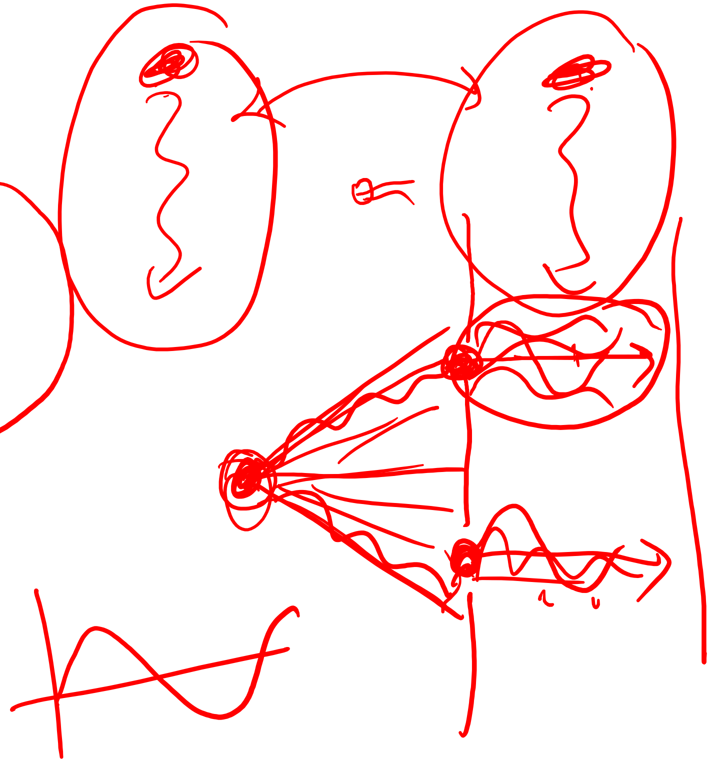
Coherent Sources

- Two sources are said to be coherent if -

    -they emit light waves of same frequency,

    -have zero or constant phase difference

- Coherent sources are monochromatic
- Two independent sources cannot be coherent.
- Coherent sources are experimentally obtained by a single parent source divided in two parts using slits or reflection/refraction.



Interference of light

The redistribution of light energy obtained by the superposition of light waves from two coherent sources of light.

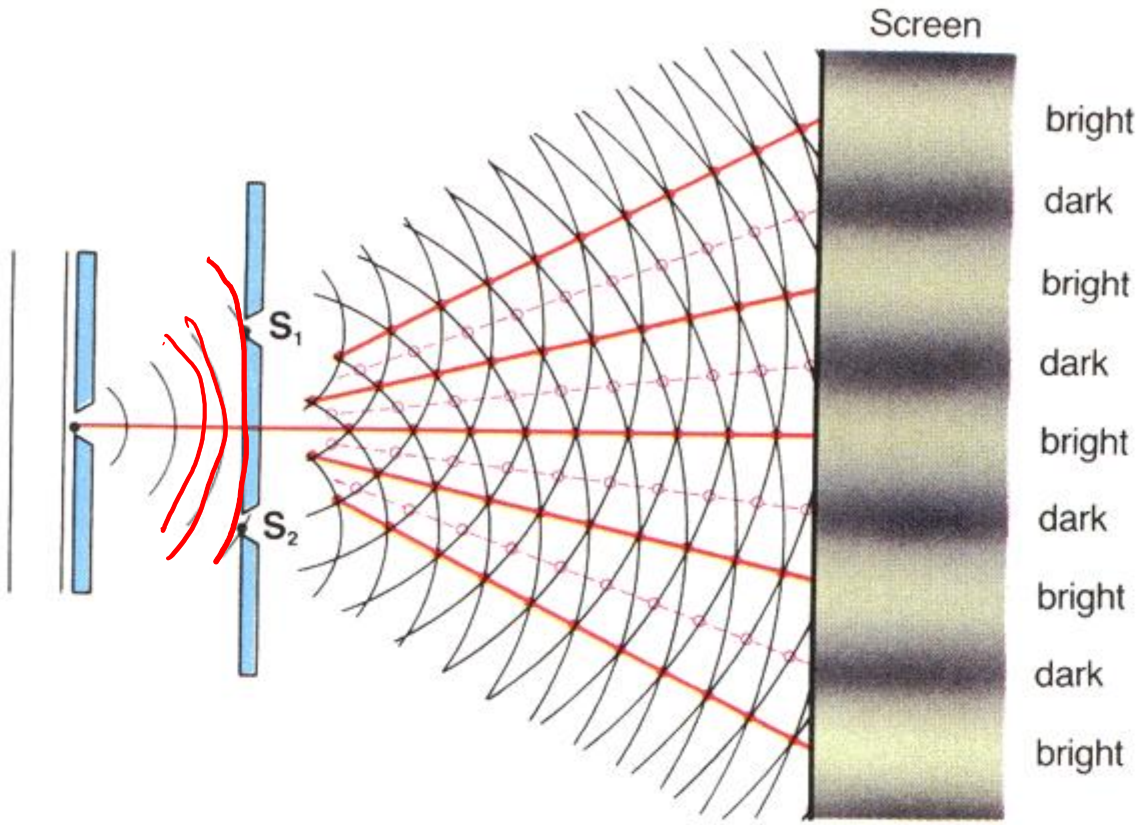
- The resultant light intensity at any point depends on the phase difference between two waves and is given by the algebraic sum of the instantaneous amplitude of the two waves

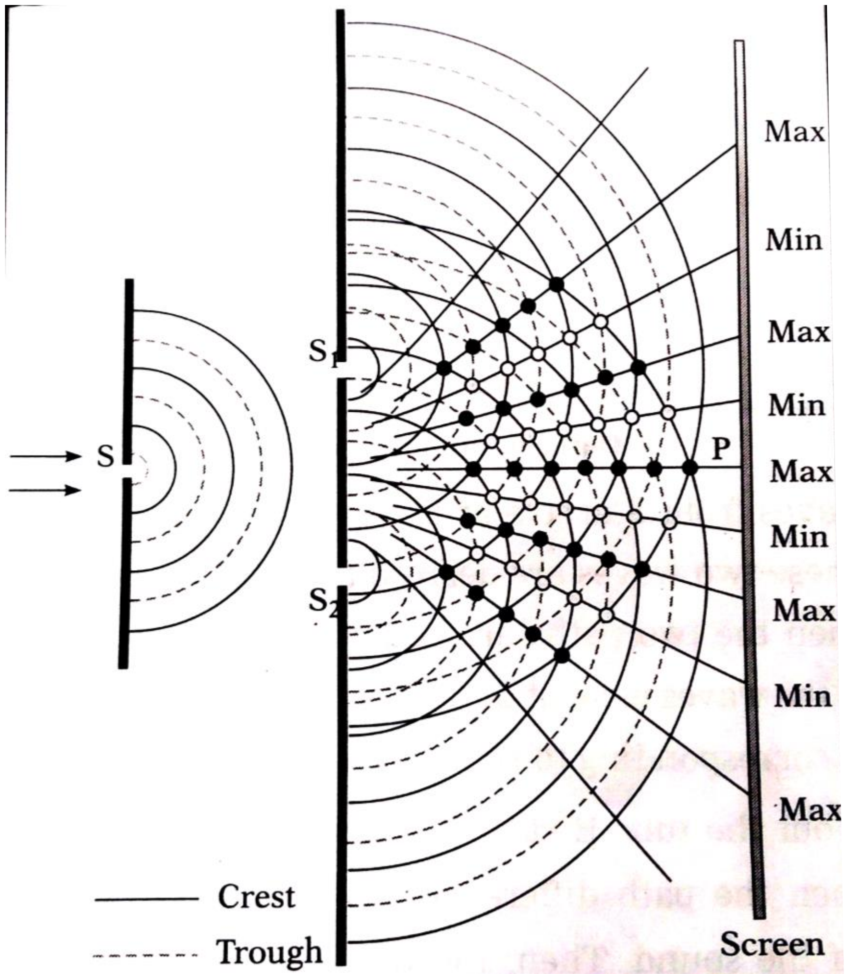
Interference of light

At places where, crest of one wave falls on the crest of other wave, or trough falls over trough, the amplitude and energy are maximum. This is called <u>constructive interference</u>.

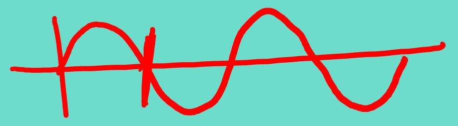
When crest falls over trough, the amplitude and energy are minimum. This is <u>destructive interference</u>.

Interference of light



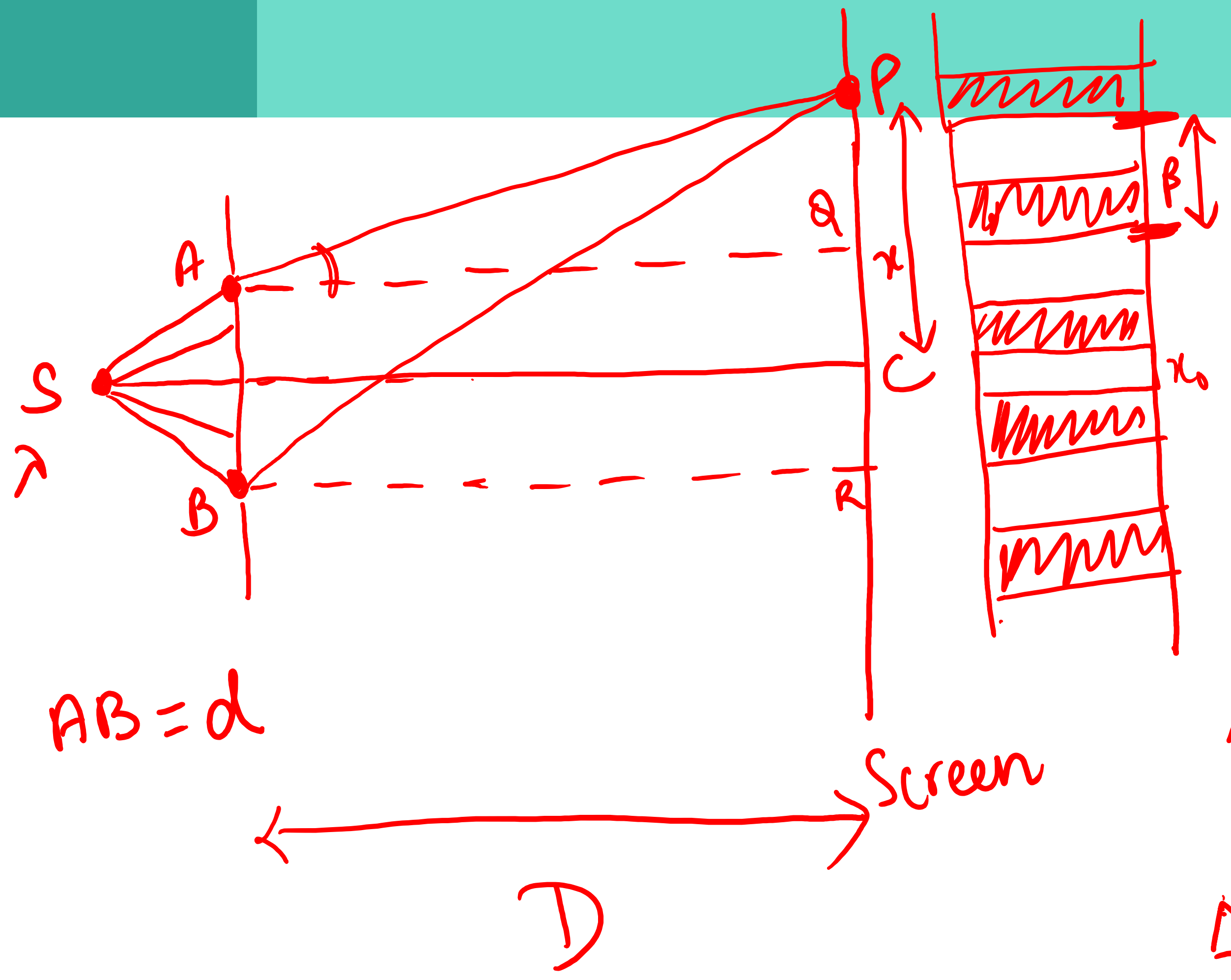


Theory of Interference



= in phase

Half λ's = out of phase



AC = BC = Bright band at center

Let $PC = x$

Path diff $= BP - AP = ??$

$QC = CR = d/2$

$PQ = x - d/2$ $\quad$ $PR = x + d/2$

$\Delta PRB \rightarrow (BP)^2 = D^2 + \left(x + \frac{d}{2}\right)^2$

$\Delta PQA \rightarrow (AP)^2 = D^2 + \left(x - \frac{d}{2}\right)^2$

breadth of single fringe $= \beta/2$

Theory of Interference

$99 \simeq 100 \simeq 101$

$\simeq 100$

β = fringe width

$$\begin{array}{r} 101 \\ 100 \\ \hline 001 \end{array}$$

$(BP)^2 - (AP)^2 = 2xd$

$BP - AP = \boxed{\dfrac{2xd}{BP + AP}}$

Approx $BP \simeq AP \simeq D$

$$\boxed{BP - AP = \frac{xd}{D}}$$

Path diff.

Phase diff: $\dfrac{2\pi}{\lambda} \dfrac{xd}{D}$

Bright:

$\dfrac{xd}{D} = n\lambda \quad n = 0, 1, 2, 3 \ldots$

$x = \dfrac{n\lambda D}{d}$;

$n = 0, \quad x_0 = 0$

$n = 1 \quad x_1 = \dfrac{\lambda D}{d}$

$n = 2 \quad x_2 = \dfrac{2\lambda D}{d}$

$$\underbrace{\begin{array}{l} x_3 - x_2 = \\ x_2 - x_1 = \\ x_1 - x_0 = \dfrac{\lambda D}{d} \end{array}}_{\beta}$$

Dark

$\dfrac{xd}{D} = (2n+1)\dfrac{\lambda}{2}$

$x_0 = \dfrac{\lambda D}{2d}$

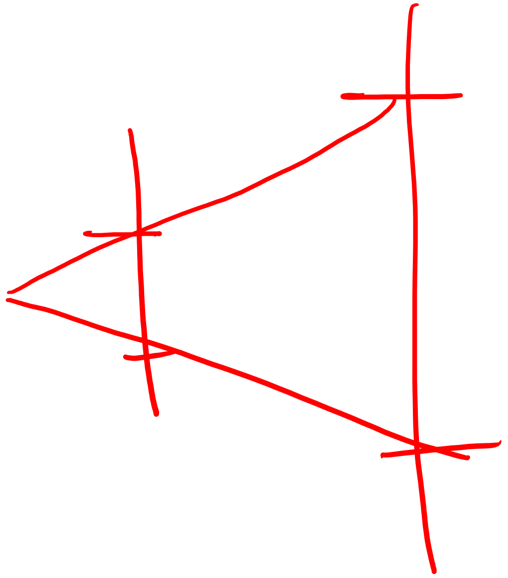
$x_1 = \dfrac{3}{2}\dfrac{\lambda D}{d}$

$x_2 =$

Fringe Width

Important formula to remember:

$$\beta = \lambda D/d$$



Therefore, fringe width is:

1. *Directly proportional to wavelength of light*
2. *Directly proportional to distance D from the screen*
3. *Inversely proportional to the distance d between the two scources*