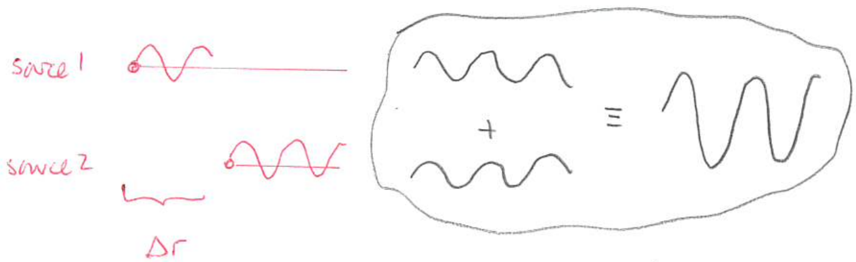
Weds: Review

Thurs: Exam III

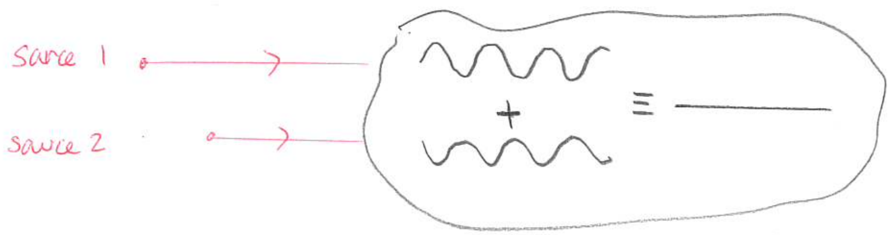
Interference of continuous waves

If there are two or more waves on a medium then they will interfere and form a superposition. For traveling sinusoidal waves the two extreme cases are:



→ **Constructive interference**

* superposition has a large amplitude
* occurs when $\Delta r = \lambda, 2\lambda, \ldots, n\lambda, \ldots$



→ **Destructive interference**

* superposition has zero amplitude
* occurs when $\Delta r = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots, \frac{2n-1}{2}\lambda, \ldots$

The amplitude of the wave is related to the intensity (in the case of light) and we can check for instances where destructive/constructive interference occurs.

Observations of interference

Consider waves that propagate in two dimensions. Then overlapping waves produce particular characteristic patterns.

Demo: PhET Wave Interference

- water waves
  - observe nodal lines / antinodal lines.

We see that there are:

Antinodal lines → constructive interference occurs along these
Nodal " → destructive " " " "

The locations of these lines depend on:

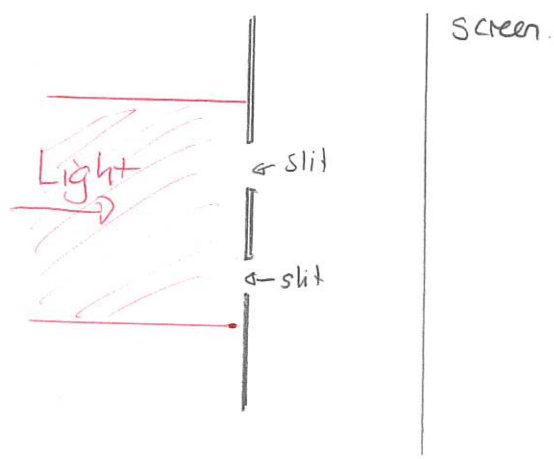
1) separation of sources
2) wavelengths of waves.

These can be demonstrate with

1) water waves – Loyola Univ Video ~ 0:30
2) sound waves – Two tuning forks.

Double Slit Experiment

We can do similar experiments by illuminating two narrow slits with light and observe the transmitted light on a distant screen.



Warm Up 1

Demo: PASCO laser + slits.

The actually pattern on the screen is a series of bright and dark spots.

We explain this by:

1) the incident light consists of a wave that arrives at both slits.

2) the wave propagating past a single slit spreads circularly beyond the slit.

3) there will be two overlapping waves beyond the slits. At some locations they interfere constructively (bright fringes). At other locations they interfere destructively (dark fringes).

Slide 1

Warm Up 2

Slide 2

The results of the double slit experiment immediately suggest:

> Light behaves like a wave

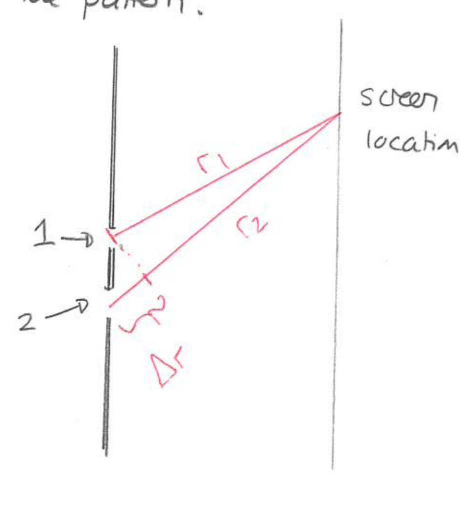
Double Slit Interference Pattern

We now ask whether we can predict features of the interference pattern produced by double slits:

* where do the bright and dark fringes occur?
* what is the intensity at any point along the pattern?

The key idea is:

> The waves that reach a given screen location will travel different distances from their respective slits. This will shift one arriving wave relative to the other

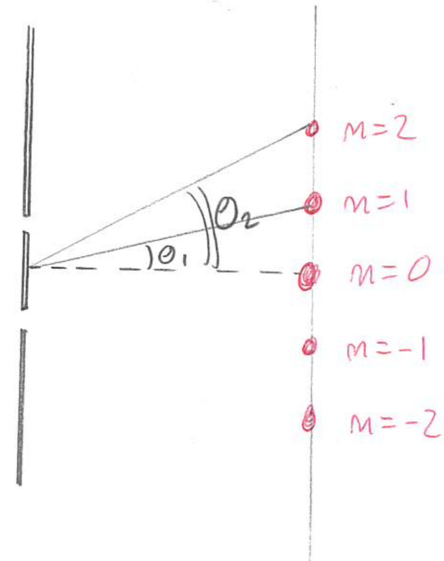


Let $r_1 =$ distance from upper slit to screen

$r_2 =$ " " lower " " "

$\Delta r = r_1 - r_2$

We can then apply the rules ($\Delta r = m\lambda$) to find conditions for constructive interference and bright spots. We can label the bright fringes and their angular locations as illustrated. Let



$\theta_1 =$ angle from midpoint line to fringe $m=1$

$\theta_2 =$ " " " " " " $m=2$

⋮

We want a rule for θ_m.

Quiz 1 ~50% → 80%

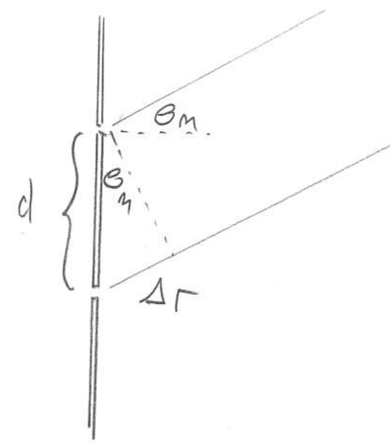
Quiz 2 70%

For the bright fringe labeled m we see that

$$\Delta r = m\lambda$$

When the screen is far from the slits relative to the slit spacing some simply geometry gives θ_m via:

$$\frac{\Delta r}{d} = \sin\theta_m \Rightarrow \Delta r = d\sin\theta_m.$$



Combining gives:

> For a double slit with slit separation d and which is illuminated by light with wavelength λ, the m^{th} bright fringe occurs at angle θ_m, s.t.
>
> $$d\sin\theta_m = m\lambda$$

Quiz 3

Example: "Monochromatic light is incident on a double slit with spacing 0.0010m. The m=1 fringe appears at 0.36°. Determine the wavelength of the light.

Answer: $m=1$ and $d\sin\theta_m = m\lambda$

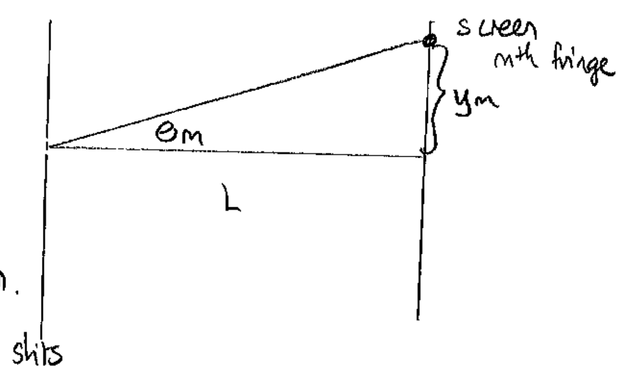
$$\Rightarrow d\sin\theta_1 = \lambda$$

$$\Rightarrow 0.0010m \sin(0.36°) = \lambda$$

$$\Rightarrow \lambda = 6.3\times10^{-7}m = 630nm$$

Note that we can approximate the "vertical" position of the fringes via:

$$y_m \approx m\frac{\lambda}{d}L$$



where L is the distance from the slits to screen.

Derivation: $\sin\theta_m = \frac{y_m}{\sqrt{L^2+y_m^2}}$

and if $y_m \ll L$ then $\sin\theta_m \approx \frac{y_m}{L}$

$$\Rightarrow d\frac{y_m}{L} \approx m\lambda \quad \Rightarrow y_m \approx m\frac{\lambda L}{d}$$