Phys 112 2019

Lecture 25

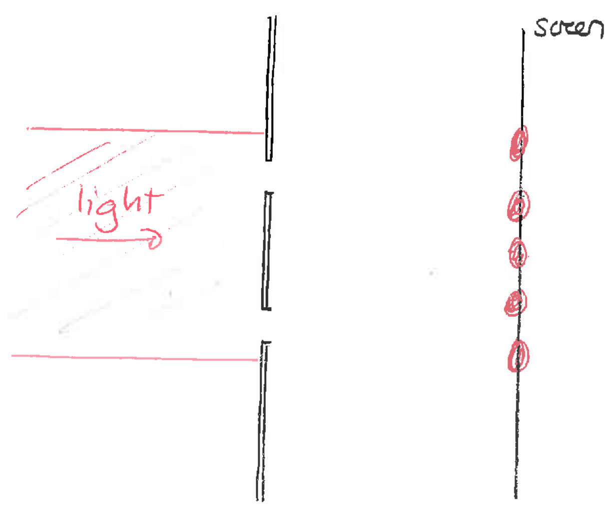
Tues: Discussion / quiz

Supp Ex 81, 82, 83, 84, 85, 86, 87

Weds: Lecture PRELABS

Double slit interference

We can observe interference of two light waves via a double slit experiment in which light is incident upon two narrowly spaced slits. We observe a pattern of bright and dark spots (fringes) on a distant screen.



Demo: PASCO slits + laser

Warm Up 1

We explain this pattern by:

1) the incident light consists of a wave arriving at each slit
2) the wave propagates circularly beyond each slit
3) there will be two waves that overlap beyond the slits. Along some lines they interfere constructively (brightest) and along others destructively (darkest).

Slide 1

This leads to the conclusion:

Light behaves like a wave

We can also see that the location of bright and dark fringes will depend on:

1) separation between the slits
2) wavelength of the light.

Demo: PhET wave interference

→ Slits → two slits

→ Adjust to red locate first minimum

→ Adjust ~~or~~ to blue ⇒ change.

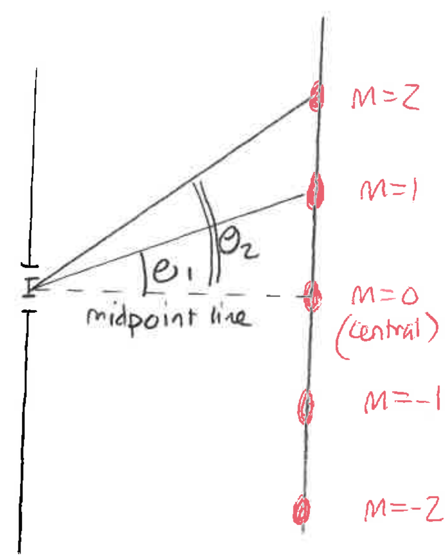
Slide 2

Analyzing a double slit pattern

The wave picture of light can predict the exact intensity of the light anywhere on the screen. We ask a more limited question:

"Where will the bright fringes be located?"

To answer this we first need to label the fringes. We use the integer "m" counting outward from the midpoint line. We can then represent the position of the fringes using the angle from the midpoint line.

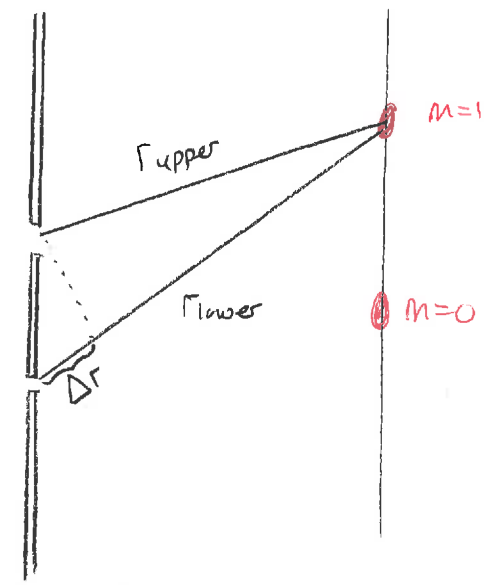


Thus

θ_1 = angle from midpoint line to $m=1$ bright fringe

θ_2 = " " " " " $m=2$ " "

We then use the fact that bright fringes result from constructive interference. If we consider the slits as two sources then the difference in distance traveled



$$\Delta r = r_{lower} - r_{upper}$$

amounts to the "separation between the sources".

Warm Up 2

Then recall

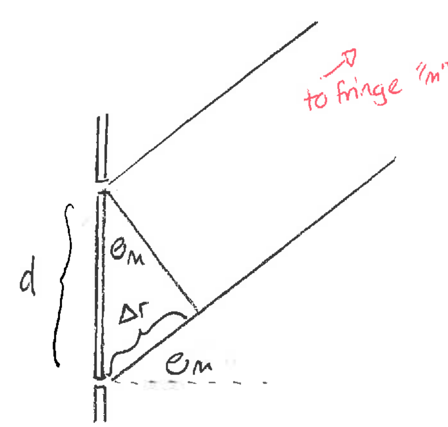
> If $\Delta r = 0, \pm\lambda, \pm 2\lambda, \pm 3\lambda$ then the waves interfere constructively and produce a bright fringe.

For the $m=0$ bright fringe $\Delta r = 0$

$m=1$ " " $\Delta r = \lambda$

$m=2$ " " $\Delta r = 2\lambda$

Now geometry and trigonometry gives



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

But $\Delta r = m\lambda$

$$\Rightarrow \quad m\lambda = d\sin\theta_m$$

where d is the separation between the slits.

Thus:

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

Quiz 1

Demo PhET Wave Interference - Slits. Show

The angle θ_m is the angle of the m^{th} bright fringe from the central bright fringe.

88 Double slit interference pattern: small angles

Light from a HeNe laser has wavelength 632.8 nm and is incident on a pair of slits separated by 40 μm = 40000 nm. A pattern is produced on a screen a distance of 1.25 m from the laser

a) Determine the angles at which the $m = 1$, $m = 2$ and $m = 3$ bright fringes appear.

b) Determine the distance from the central bright fringe to each of the first three fringes.

c) Determine the separation between adjacent bright fringes.

Answer: a) $d \sin\theta_m = m\lambda$

$$\sin\theta_m = m \lambda/d = m \frac{632.8\,nm}{40000\,nm}$$

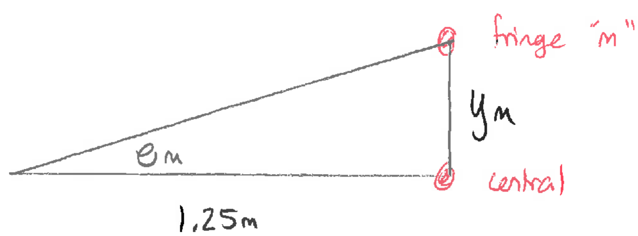
$$\Rightarrow \sin\theta_m = m\,0.0158$$

$m = 1 \Rightarrow \sin\theta_1 = 0.0158 \Rightarrow \theta_1 = 0.91°$

$m = 2 \Rightarrow \sin\theta_2 = 0.0316 \Rightarrow \theta_2 = 1.81°$

$m = 3 \Rightarrow \sin\theta_3 = 0.0474 \Rightarrow \theta_3 = 2.72°$

b)



$$\tan\theta_m = \frac{y_m}{1.25m}$$

$$\Rightarrow y_m = 1.25m \tan\theta_m$$

$m = 1 \Rightarrow y_1 = 0.0199m$

$m = 2 \Rightarrow y_2 = 0.0395m$ > separation 0.0196m

$m = 3 \Rightarrow y_3 = 0.0594m$ > separation 0.0199m

c) appears to be 0.0199m

In general if the screen is distance L from the slits and $L \gg d$; then the distance from the bright fringe "m" to the central fringe is

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