Announcements

Final exam day events (Friday, May 12, 10:00am to 12:00pm)

- 50-point multiple choice end-material test (covering material from chapters 33-36). (You get a free 8-point question!)
- 200 point comprehensive final exam, all problems (no multiple choice), about 50% emphasis on chapters 33-36

You may take neither, one, or both of these tests. Your choice. No one admitted after 10:15am!

You may spend your two hours however you see fit (all on end-material, all on final exam, some mix).

Today’s agenda:

Review of Waves.

You are expected to recall facts about waves from Physics 1135.

Young’s Double Slit Experiment.

You must understand how the double slit experiment produces an interference pattern.

Conditions for Interference in the Double Slit Experiment.

You must be able to calculate the conditions for constructive and destructive interference in the double slit experiment.

Intensity in the Double Slit Experiment.

You must be able to calculate intensities in the double slit experiment.

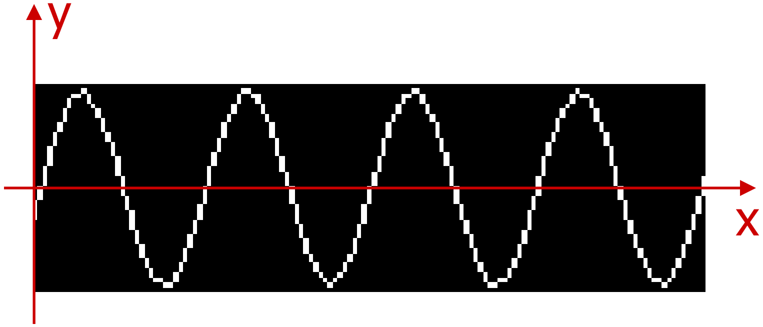
Review of Waves

Wave:

•variation (disturbance) of physical quantity that propagates through space

- often: **oscillation** in space and time

$$y(x,t) = A \sin(kx - \omega t) .$$



- phase of this wave

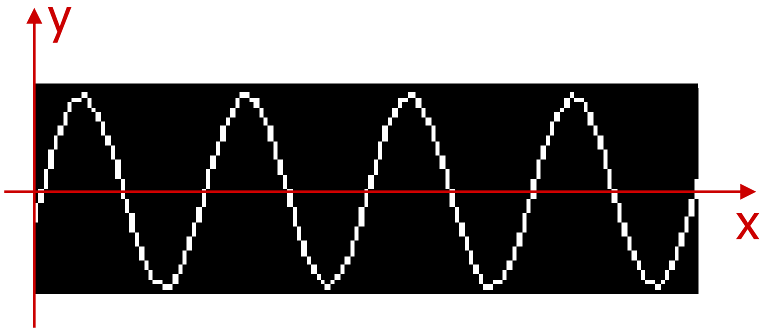
$$\theta(x,t) = kx - \omega t .$$

- if you are moving with the wave, phase is constant (for $\Theta=\pi/2$, you sit at the maximum)

How fast does the wave move?

- if θ is constant with time $$0 = \frac{d\theta}{dt} = k\frac{dx}{dt} - \omega\ .$$

- **phase velocity:** $$v_p = \frac{dx}{dt} = \frac{\omega}{k}\ .$$



Imagine yourself riding on any point on this wave. The point you are riding moves to the right. The velocity it moves at is v_p.

If the wave is moving from left to right then ω/k must be positive.

Superposition—a Characteristic of All Waves

When waves of the same nature arrive at some point at the same time, the corresponding physical quantities add.

Example:

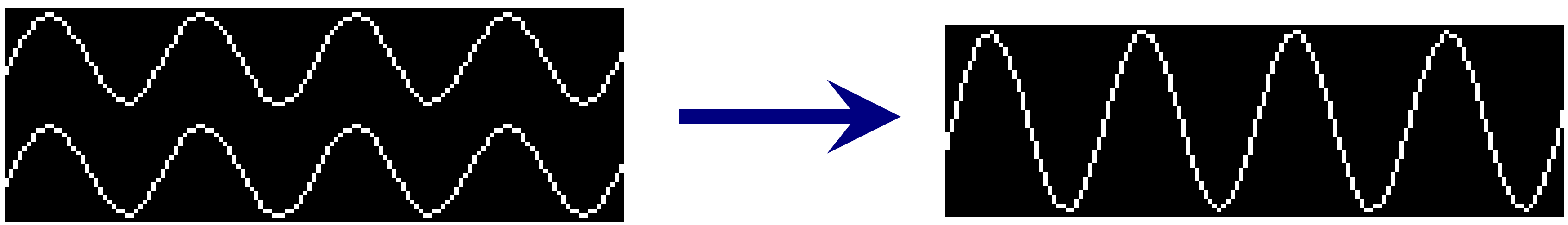
If two electromagnetic waves arrive at a point, the electric field is the sum of the (instantaneous) electric fields due to the two waves.

Implication:

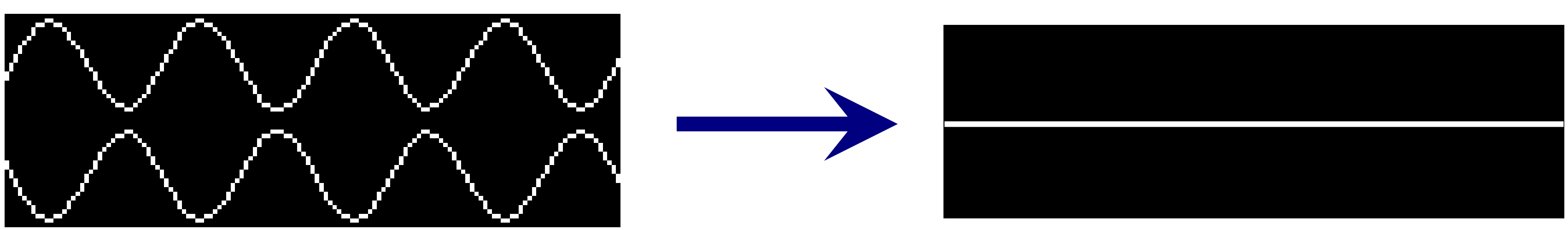
Intensity of the superposed waves is proportional to the square of the amplitude of the resulting sum of waves.

Interference—a Result of the Superposition of Waves

Constructive Interference: If the waves are in phase, they reinforce to produce a wave of greater amplitude.

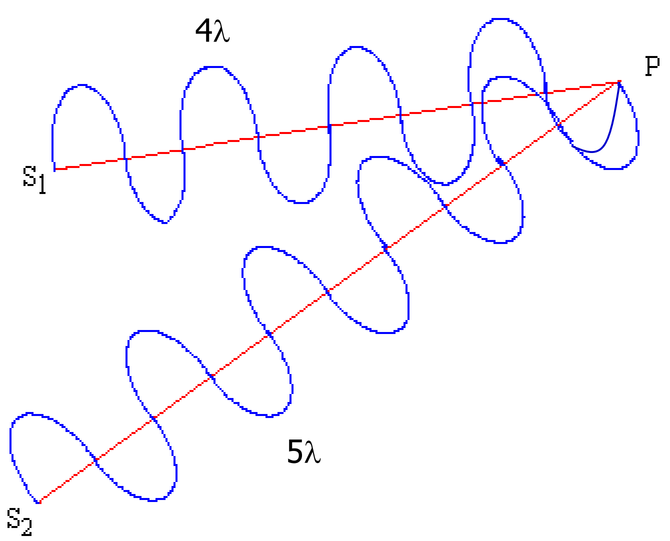


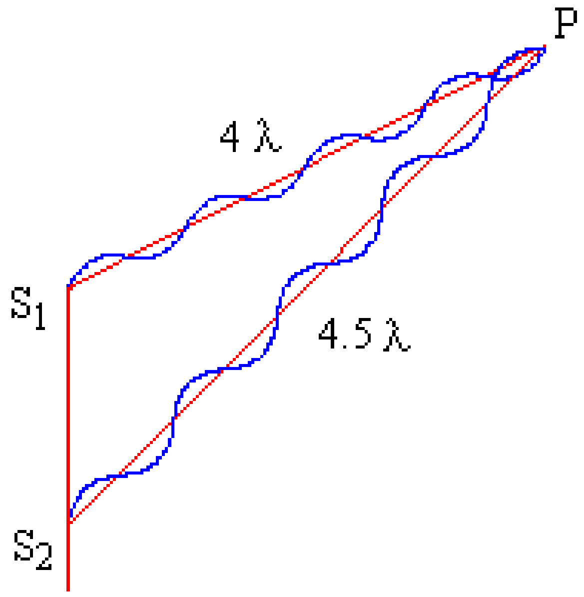
Destructive Interference: If the waves are out of phase, they reinforce to produce a wave of reduced amplitude.



Optical path length difference

- two sources emit waves in phase
- waves travel different distances L_1 and L_2 to point of interest
- optical path difference $\Delta L = L_1 - L_2$ determines interference





$\Delta L = m\,\lambda$

In phase—constructive

$\Delta L = (m+1/2)\,\lambda$

Out of phase—destructive

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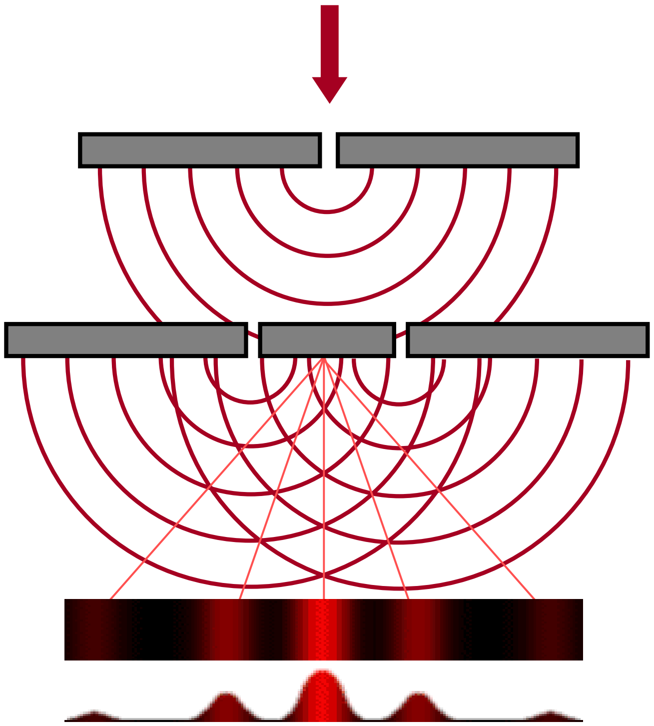
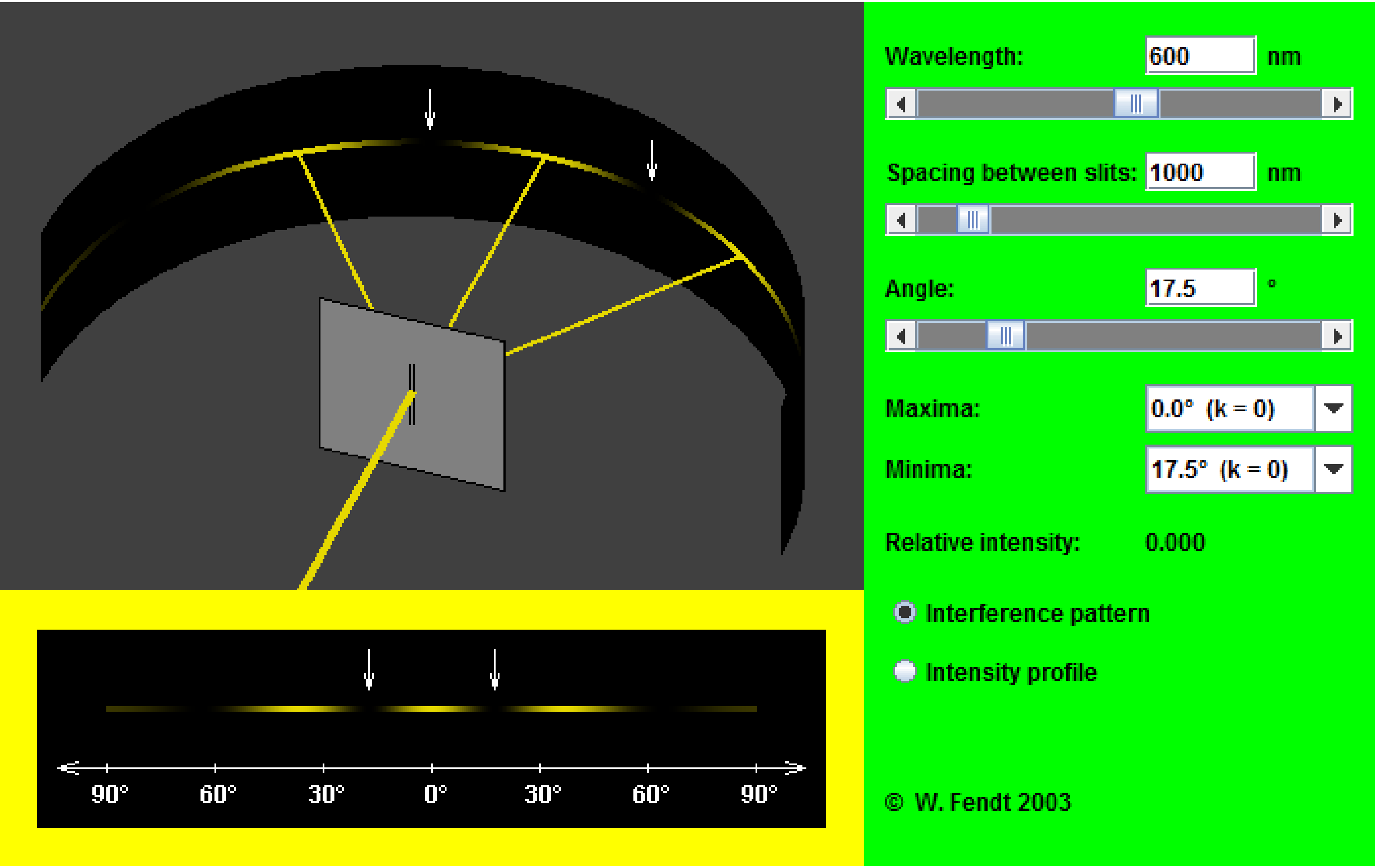
Young's Double Slit Experiment

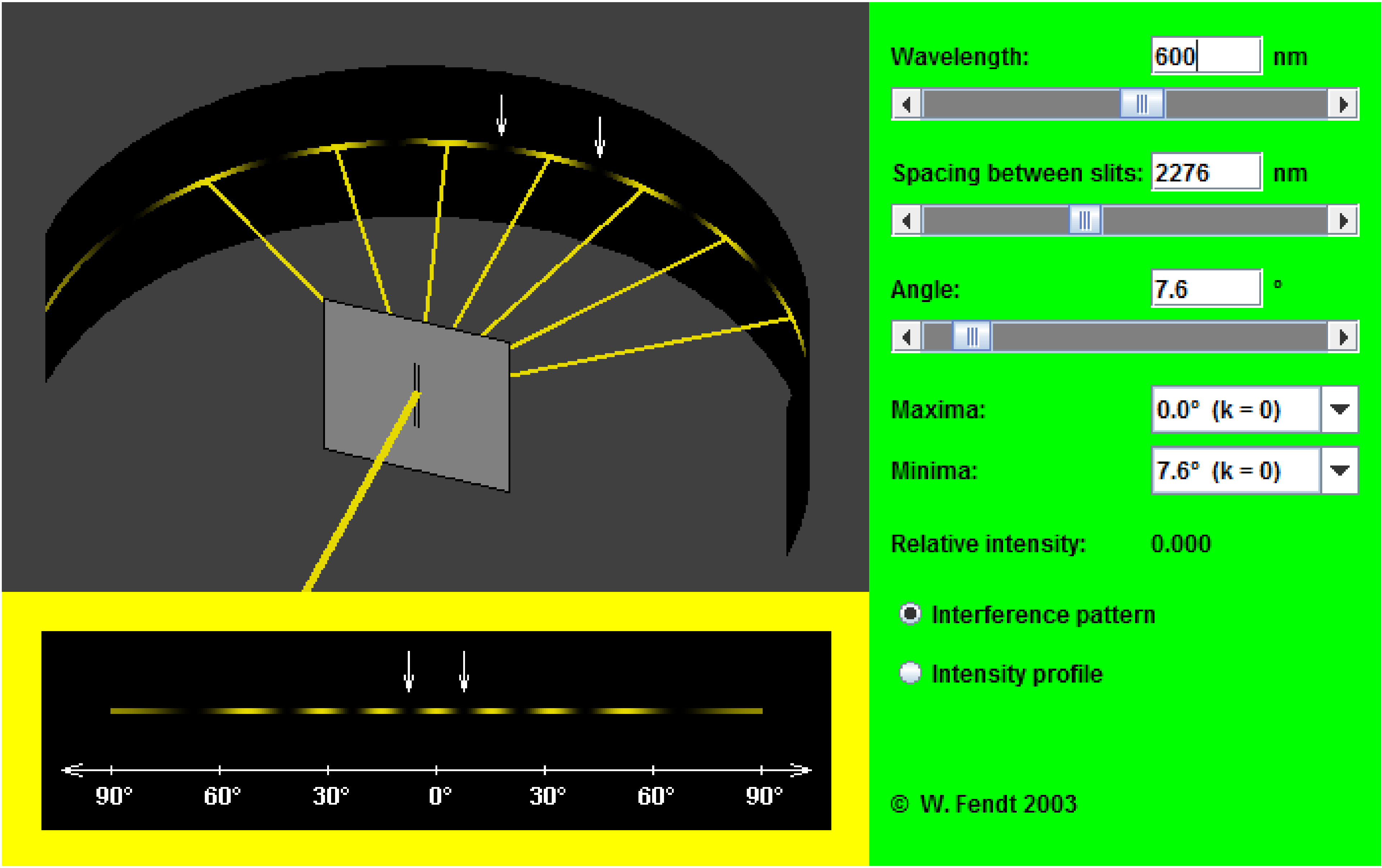
- famous experiment, demonstrates **wave nature** of light
- single light source illuminates two slits, each slit acts as secondary source of light
- light waves from slits **interfere** to produce alternating maxima and minima in the intensity



Reference and "toys:" fsu magnet lab, Colorado light cannon, wave interference, double slit.



90°
60°
30°
0°
30°
60°
90°
Wavelength:
600
nm
Spacing between slits:
1000
nm
Angle:
17.5
°
Maxima:
0.0° (k = 0)
Minima:
17.5° (k = 0)
Relative intensity:
0.000
Interference pattern
Intensity profile
© W. Fendt 2003



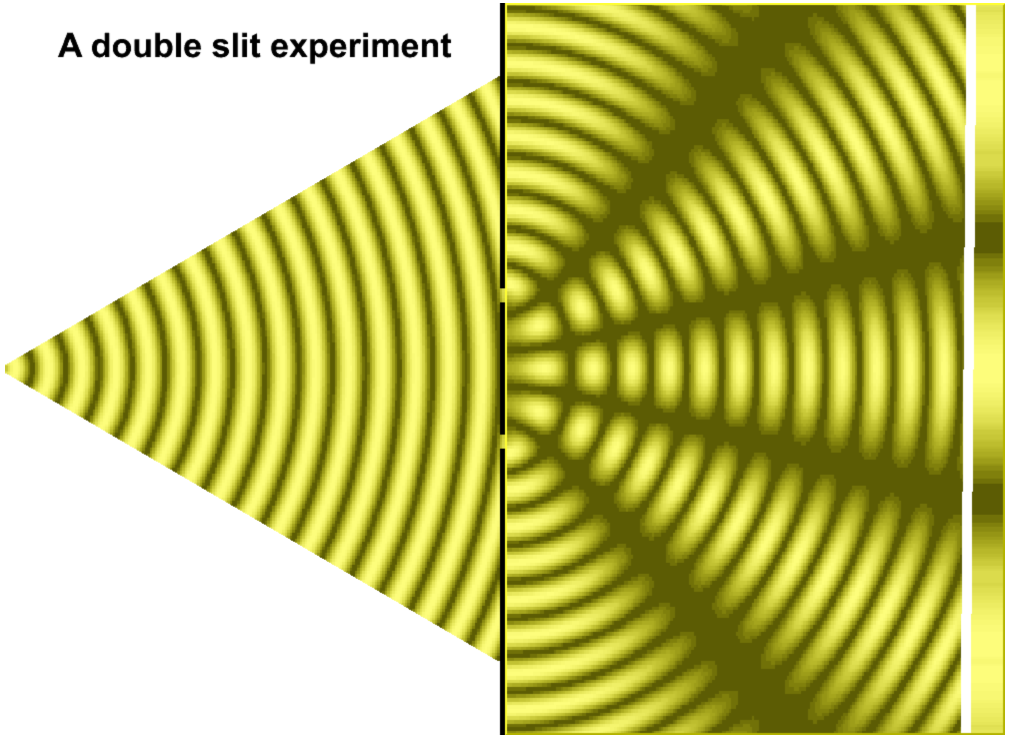
Wavelength:
600
nm
Spacing between slits:
2276
nm
Angle:
7.6
°
Maxima:
0.0° (k = 0)
Minima:
7.6° (k = 0)
Relative intensity:
0.000
Interference pattern
Intensity profile
© W. Fendt 2003
90°
60°
30°
0°
30°
60°
90°

How does this work?

At some locations on the screen, light waves from the two slits arrive **in phase** and interfere **constructively.**

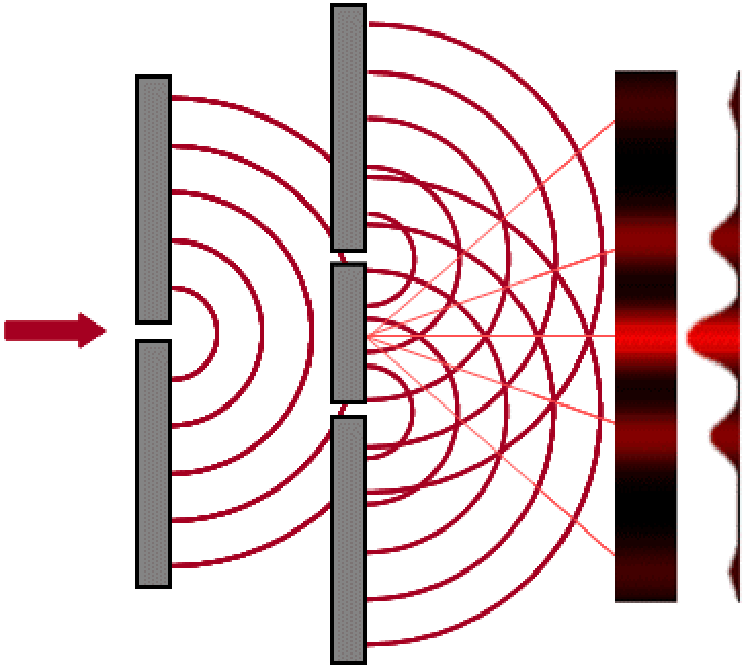
At other locations light waves arrive **out of phase** and interfere **destructively**.

A double slit experiment



Conditions for Interference

Why the double slit?
Can't I just use two flashlights?



- sources must be **coherent -** maintain a constant phase with respect to each other

- sources should be **monochromatic -** contain a single wavelength only

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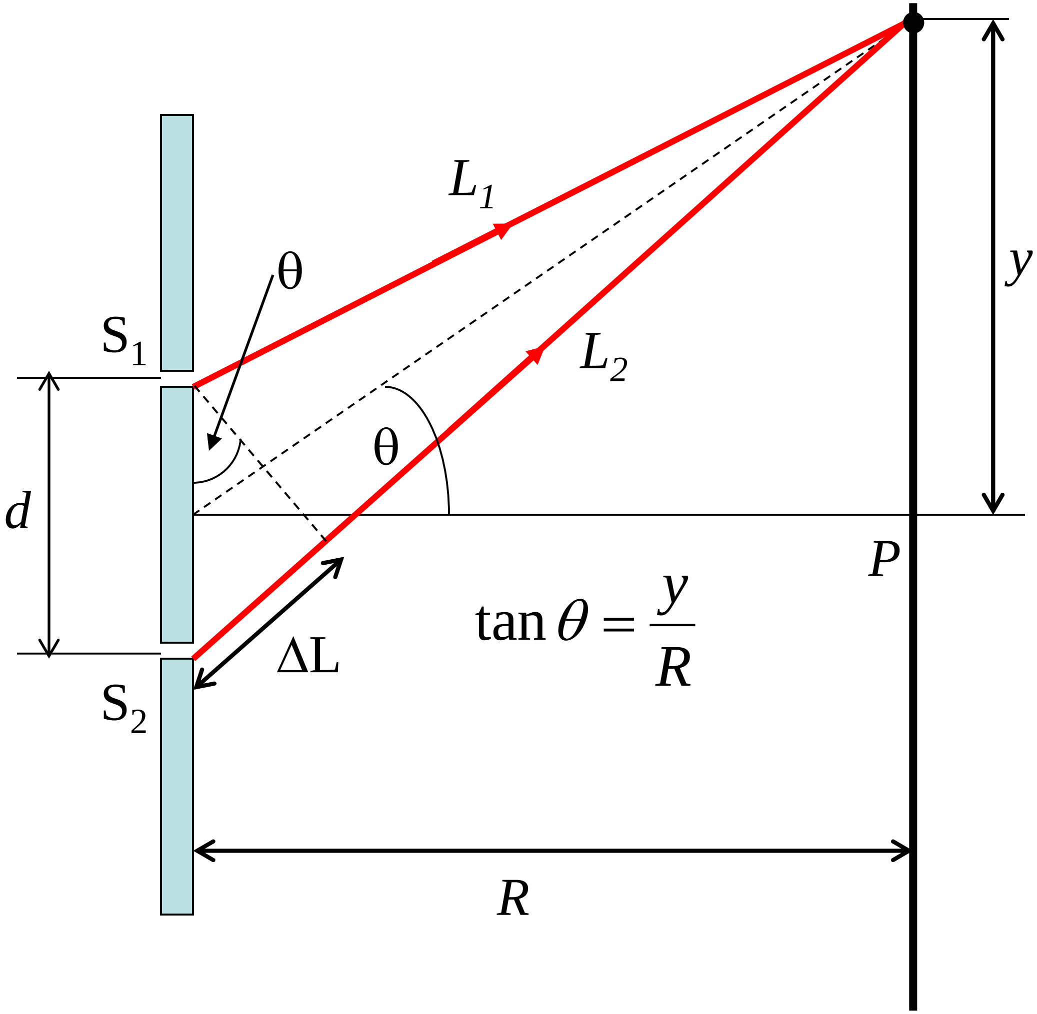
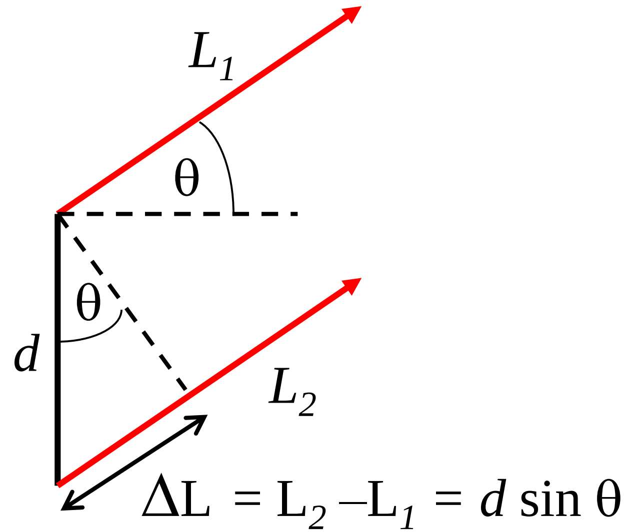
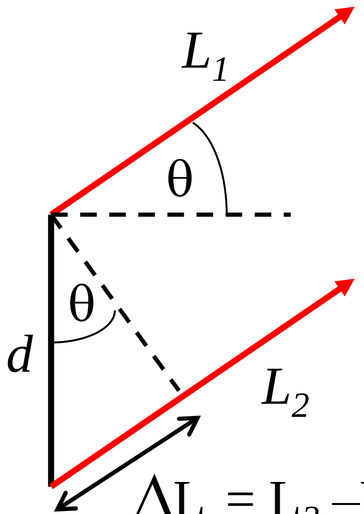


For an infinitely distant* screen:



*so that all the angles labeled θ are approximately equal



$\Delta L = L_2 - L_1 = d \sin\theta$

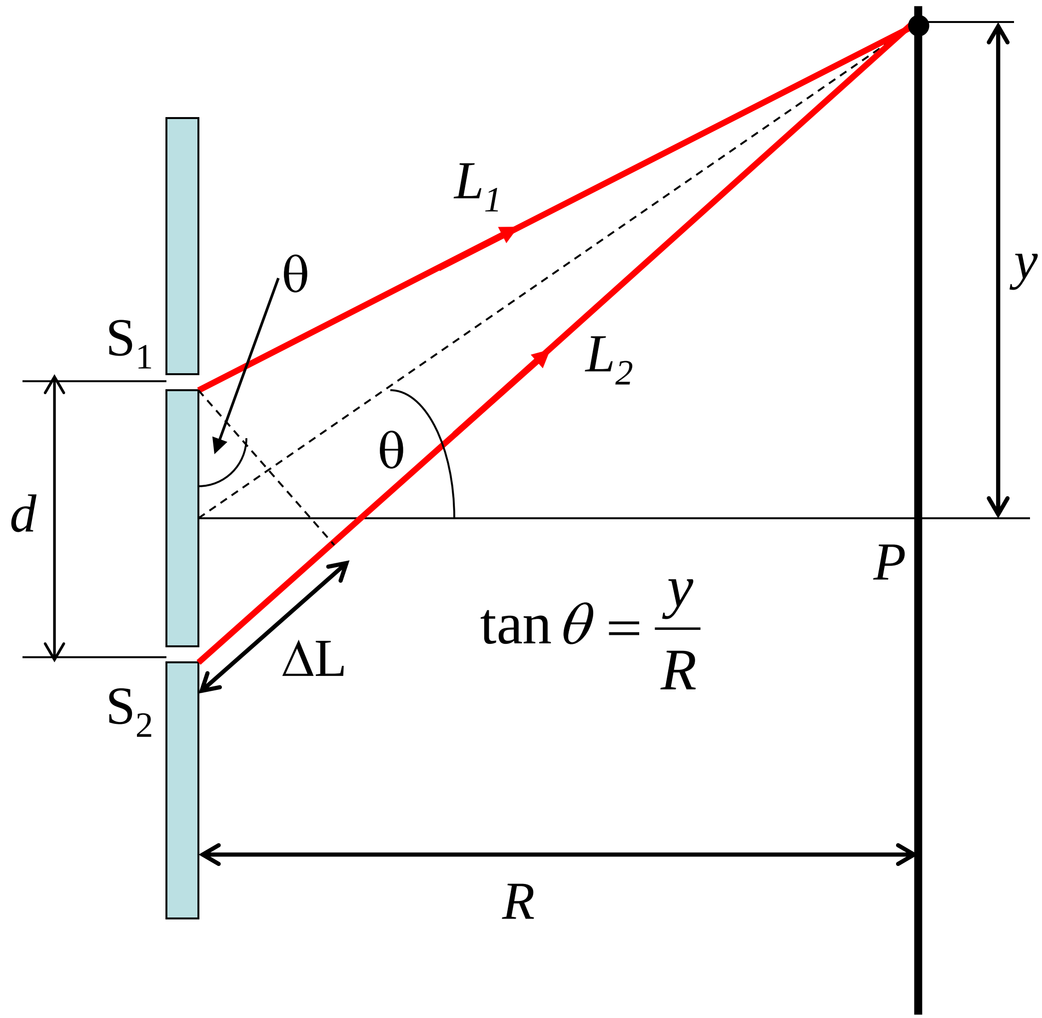
Constructive Interference:

$$\Delta L = \boxed{d \ \sin\theta = m\lambda,} \quad m = 0, \pm 1, \pm 2 \ldots$$

Destructive Interference:

$$\Delta L = \boxed{d \ \sin\theta = \left(m + \frac{1}{2}\right)\lambda,} \quad m = 0, \pm 1, \pm 2 \ldots$$

The parameter m is called the order of the interference fringe. The central bright fringe at $\theta = 0$ ($m = 0$) is known as the zeroth-order maximum. The first maximum on either side ($m = \pm 1$) is called the first-order maximum.



For small angles:

$$y = R\ \tan\theta \approx R\ \sin\theta$$

Bright fringes:

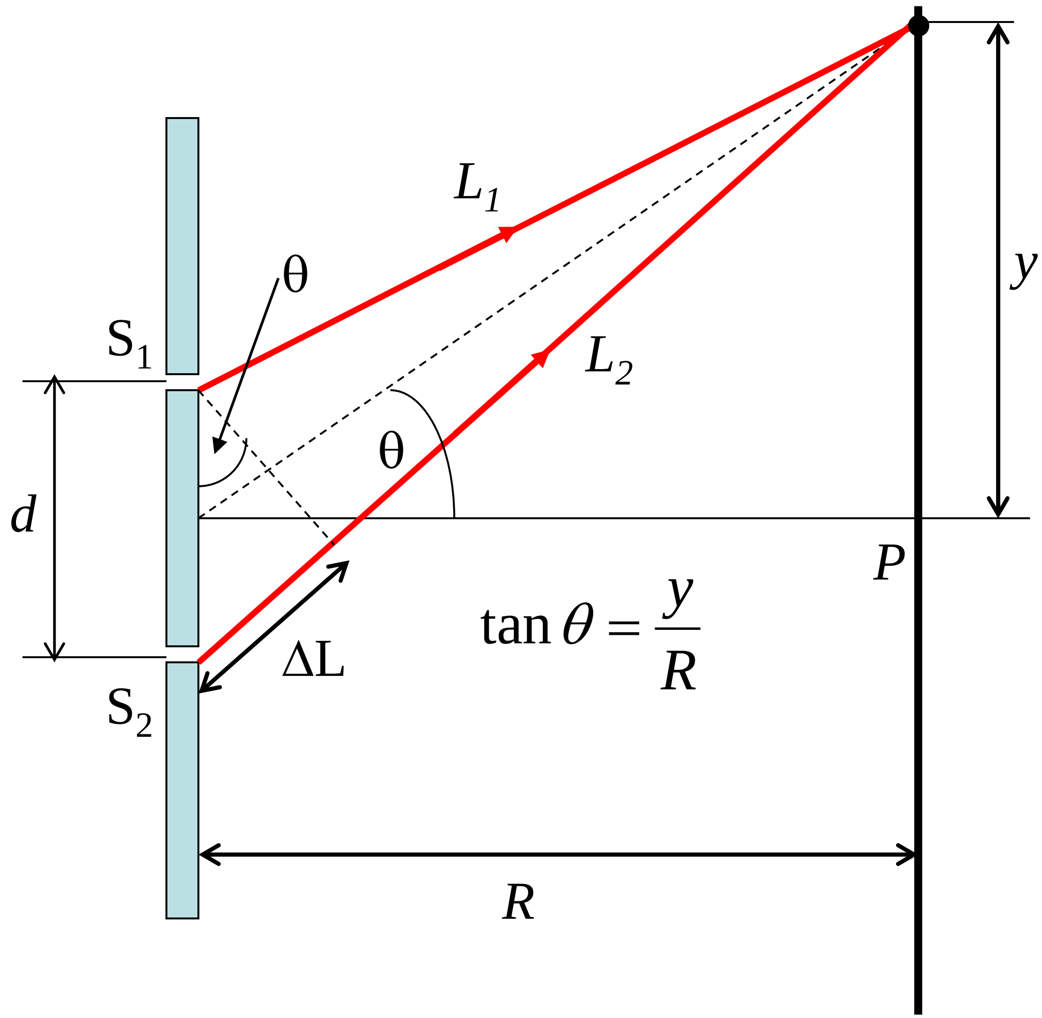
$$m\lambda = d\ \sin\theta$$

$$m\lambda = d\ \frac{y}{R}$$

$$y = \frac{\lambda R}{d} m$$

This is not a starting equation!

Do not use the small-angle approximation unless it is valid!



For small angles:

$$y = R\ \tan\theta \approx R\ \sin\theta$$

Dark fringes:

$$\left(m + \frac{1}{2}\right)\lambda = d\ \sin\theta$$

$$\left(m + \frac{1}{2}\right)\lambda = d\ \frac{y}{R}$$

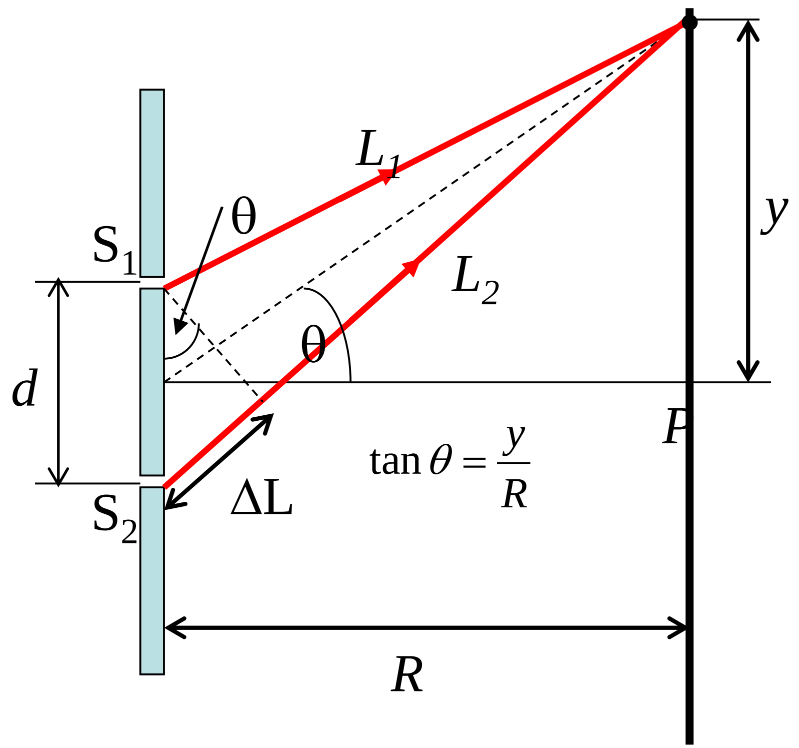
$$y = \frac{\lambda R}{d}\left(m + \frac{1}{2}\right)$$

This is not a starting equation!

Do not use the small-angle approximation unless it is valid!

Example: a viewing screen is separated from the double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe (m = 2) is 4.5 cm from the center line. Determine the wavelength of the light.

$$y = R\ \tan\theta \approx R\ \sin\theta$$



Bright fringes:

$$m\lambda = d\ \sin\theta$$

$$m\lambda = d\ \frac{y}{R}$$

$$\lambda = \frac{yd}{Rm}$$

$$\lambda = \frac{\left(4.5\times10^{-2}\ \text{m}\right)\left(3.0\times10^{-5}\ \text{m}\right)}{\left(1.2\ \text{m}\right)\left(2\right)} = 5.6\times10^{-7}\text{m} = 560\ \text{nm}$$

Example: a viewing screen is separated from the double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe (m = 2) is 4.5 cm from the center line. Find the distance between adjacent bright fringes.

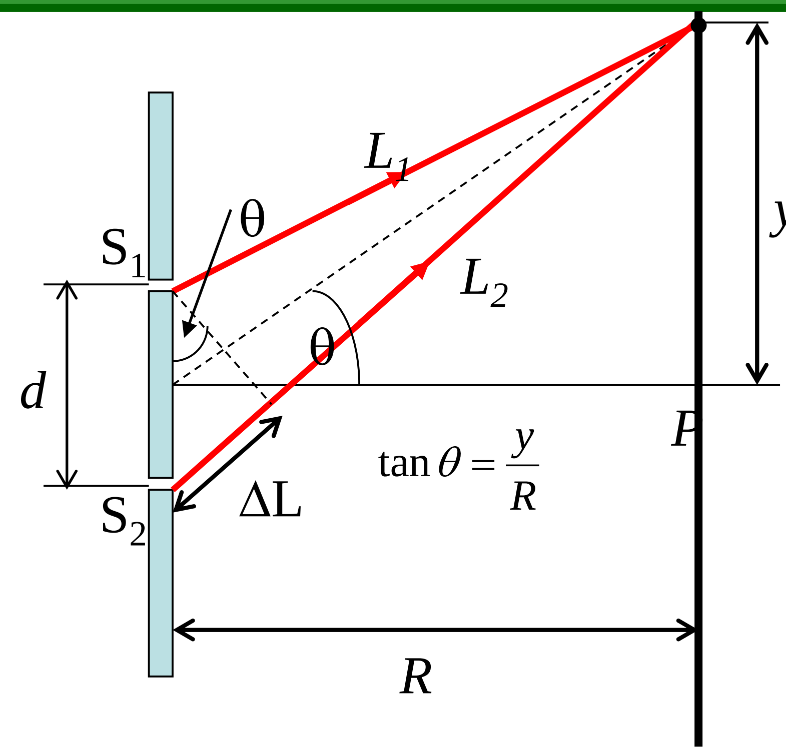
$$y = R \tan\theta \approx R \sin\theta$$

Bright fringes:

$$m\lambda = d \sin\theta$$

$$m\lambda = d \frac{y}{R}$$

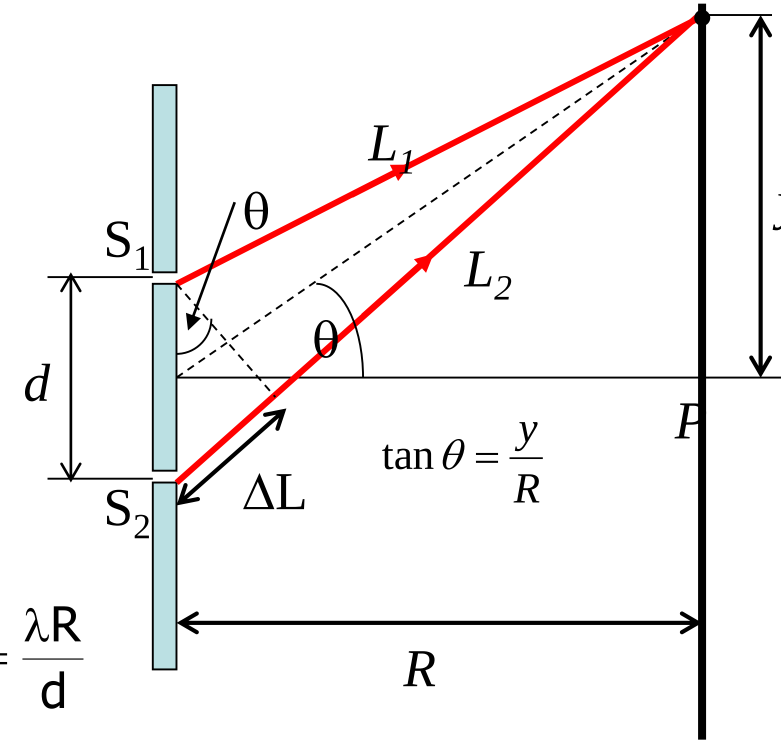
$$y = \frac{\lambda R}{d} m$$



$$y_{m+1} - y_m = \frac{\lambda R}{d}(m+1) - \frac{\lambda R}{d} m = \frac{\lambda R}{d} = \frac{(5.6\times10^{-7} m)(1.2\ m)}{(3.0\times10^{-5}\ m)} = 2.2\times10^{-2}\ m = 2.2\ cm$$

Example: a viewing screen is separated from the double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe (m = 2) is 4.5 cm from the center line. Find the width of the bright fringes.

Define the bright fringe width to be the distance between two adjacent destructive minima.



$$\left(m+\frac{1}{2}\right)\lambda = d\ \sin\theta = d\ \frac{y_{dark}}{R}$$

$$y_{dark} = \frac{\lambda R}{d}\left(m+\frac{1}{2}\right)$$

$$y_{dark,m+1}\text{-}y_{dark,m} = \frac{\lambda R}{d}\left((m+1)+\frac{1}{2}\right)-\frac{\lambda R}{d}\left(m+\frac{1}{2}\right) = \frac{\lambda R}{d}$$

$$y_{dark,m+1}\text{-}y_{dark,m} = \frac{\left(5.6\times10^{-7}\,\text{m}\right)\left(1.2\ \text{m}\right)}{\left(3.0\times10^{-5}\ \text{m}\right)} = 2.2\ \text{cm}$$

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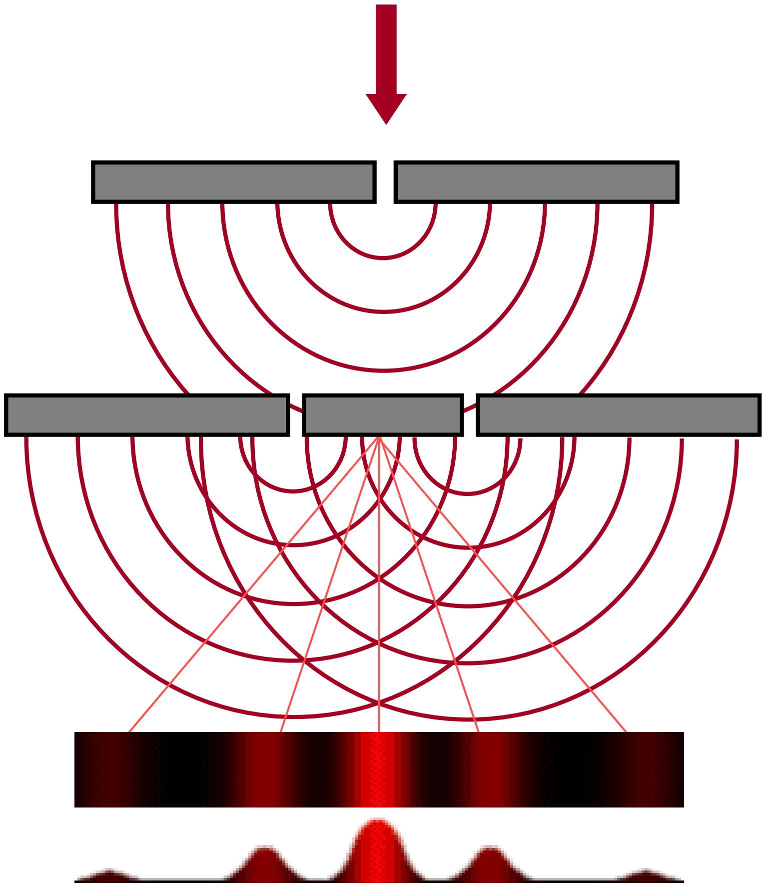
Intensity in the Double Slit Experiment

So far: positions of the minima and maxima of the double-slit interference pattern

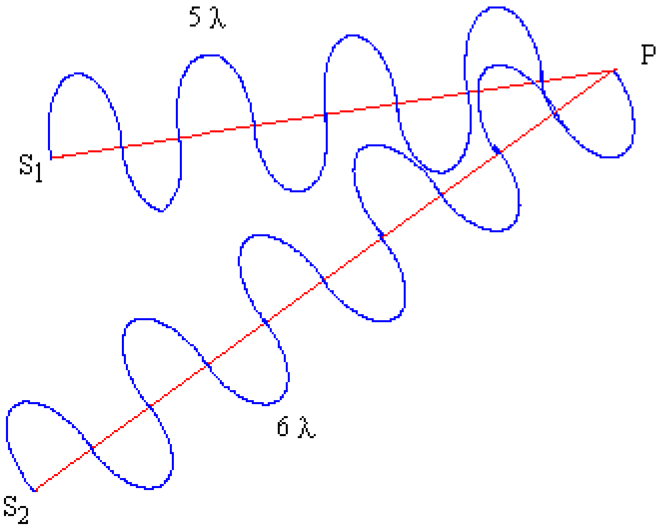
Now: light intensity at arbitrary location in interference pattern (derivation is in text book)



Recall:

- optical path length difference $\Delta L = L_1 - L_2$

- path length difference $\Delta L=\lambda$ corresponds to phase difference of $\phi=2\pi$.



- in general, path length difference ΔL corresponds to phase difference $\phi=2\pi\Delta L/\lambda$

- for the double-slit $\Delta L=d \sin\Theta$

$$\varphi = \frac{2\pi}{\lambda} d \sin\theta$$

$\varphi = \frac{2\pi}{\lambda}\Delta L$ is also "official"

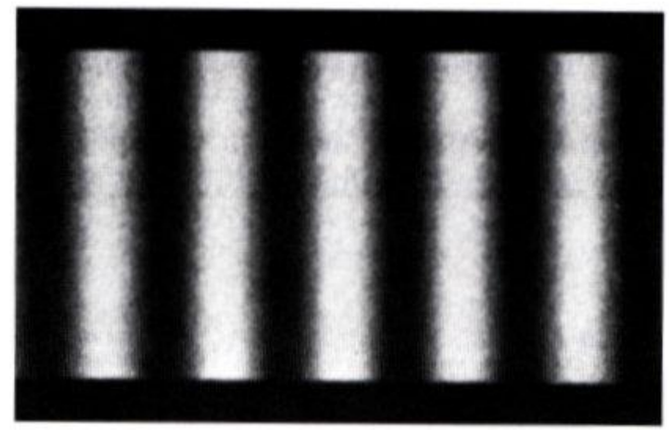
Your text writes the equation for the intensity distribution in the in terms of the phase difference on the previous slide.

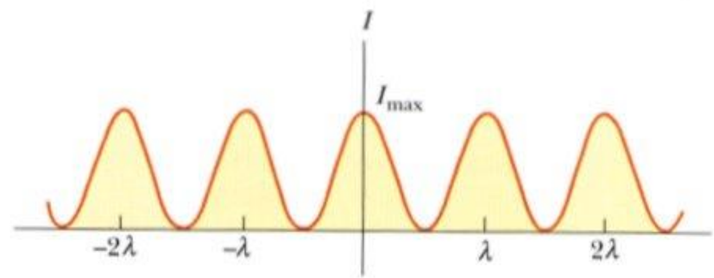
Your starting equation for the intensity is

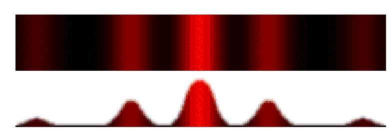
$$I = I_0 \cos^2\left(\frac{\varphi}{2}\right)$$

where I_0 is 4 times the peak intensity of either of the two interfering waves:

$$I_0 = 4I_{\text{single wave}}$$







Why did my previous diagrams show this?