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.

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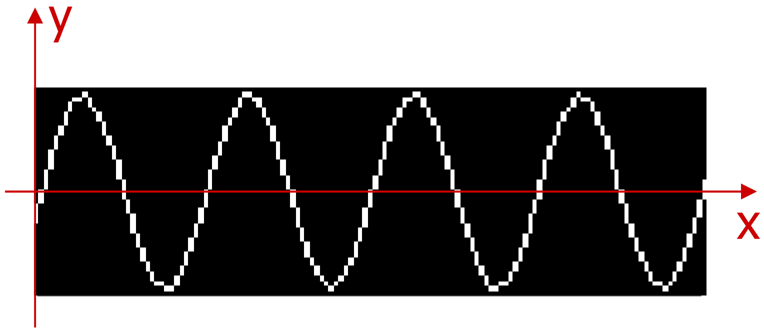
Review of Waves

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

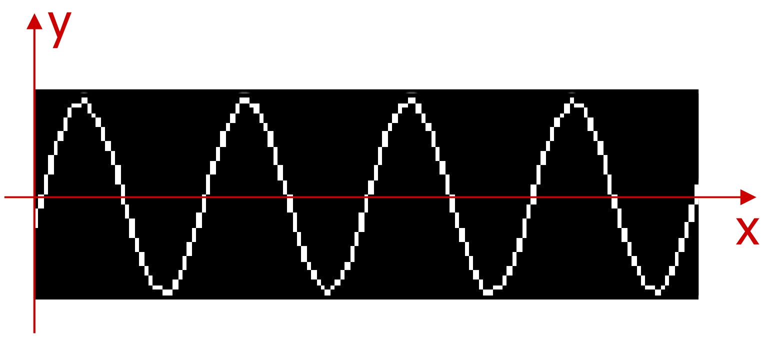
$$\theta(x,t) = kx - \omega t \,.$$

- 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:

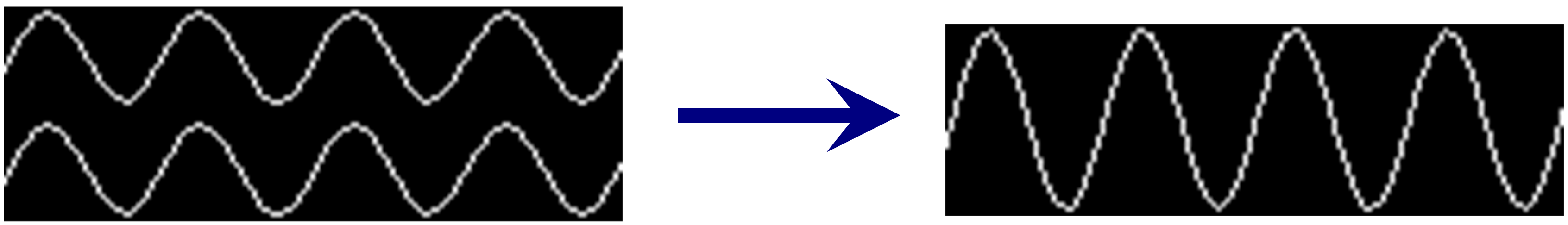
If two electromagnetic waves arrive at a point, the electric field is the sum of the (instantaneous) electric fields due to the two waves.

Implication:

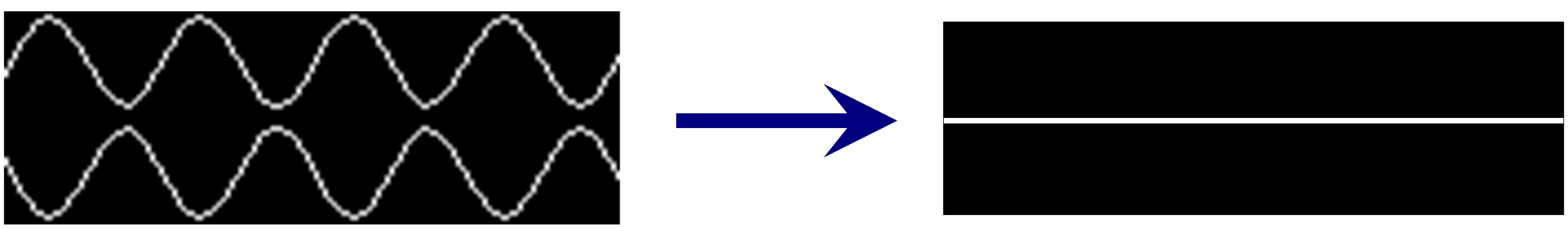
Intensity of the superposed waves is proportional to the square of the amplitude of the resulting sum of waves.

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.

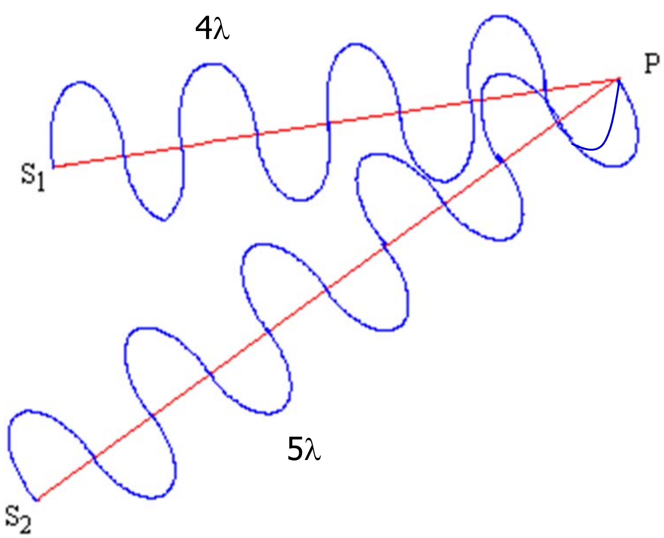


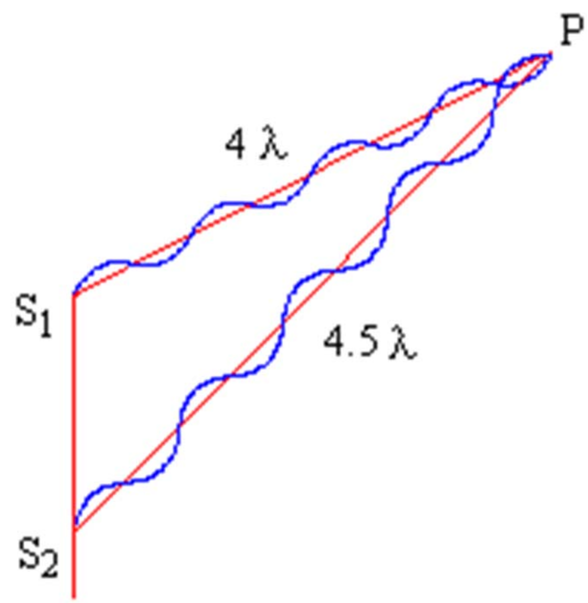
Destructive Interference: If the waves are out of phase, they reinforce to produce a wave of reduced amplitude.



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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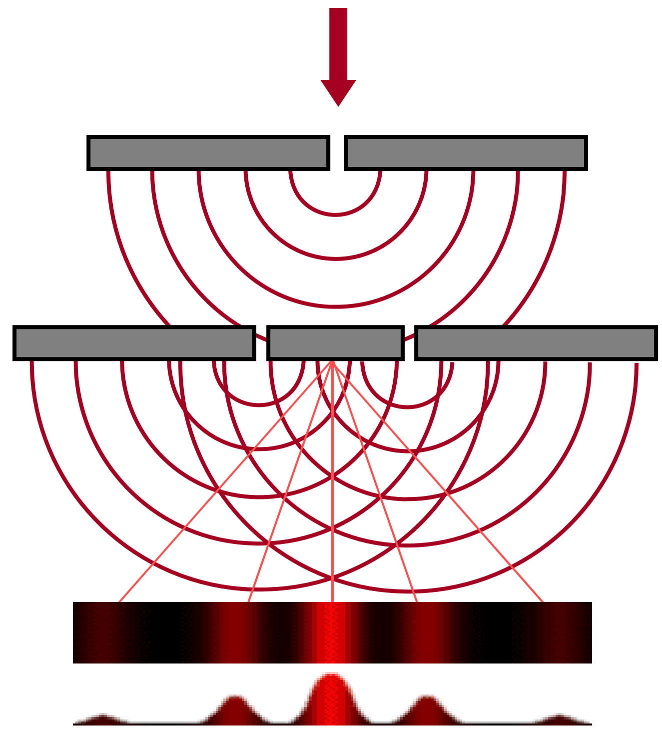
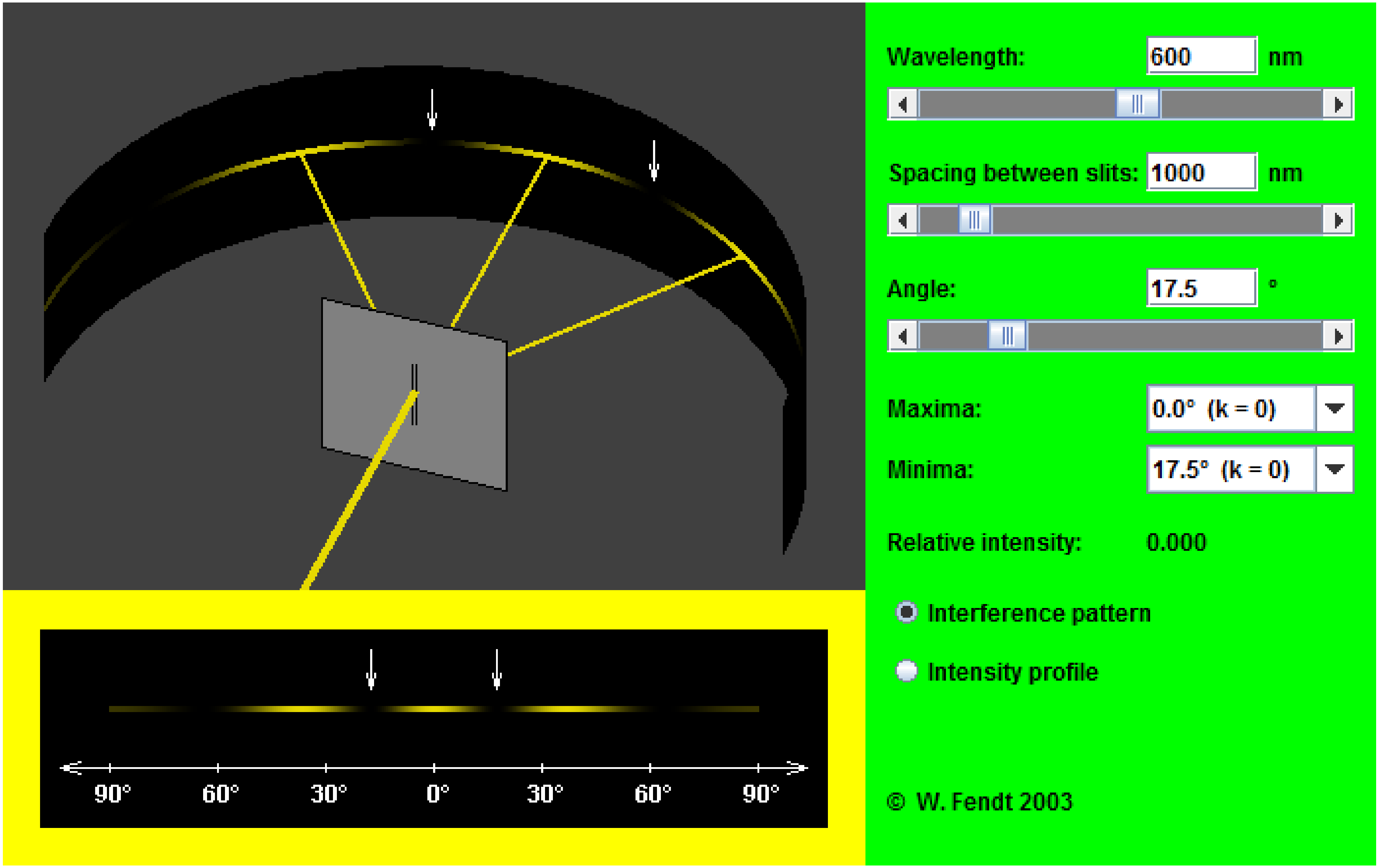
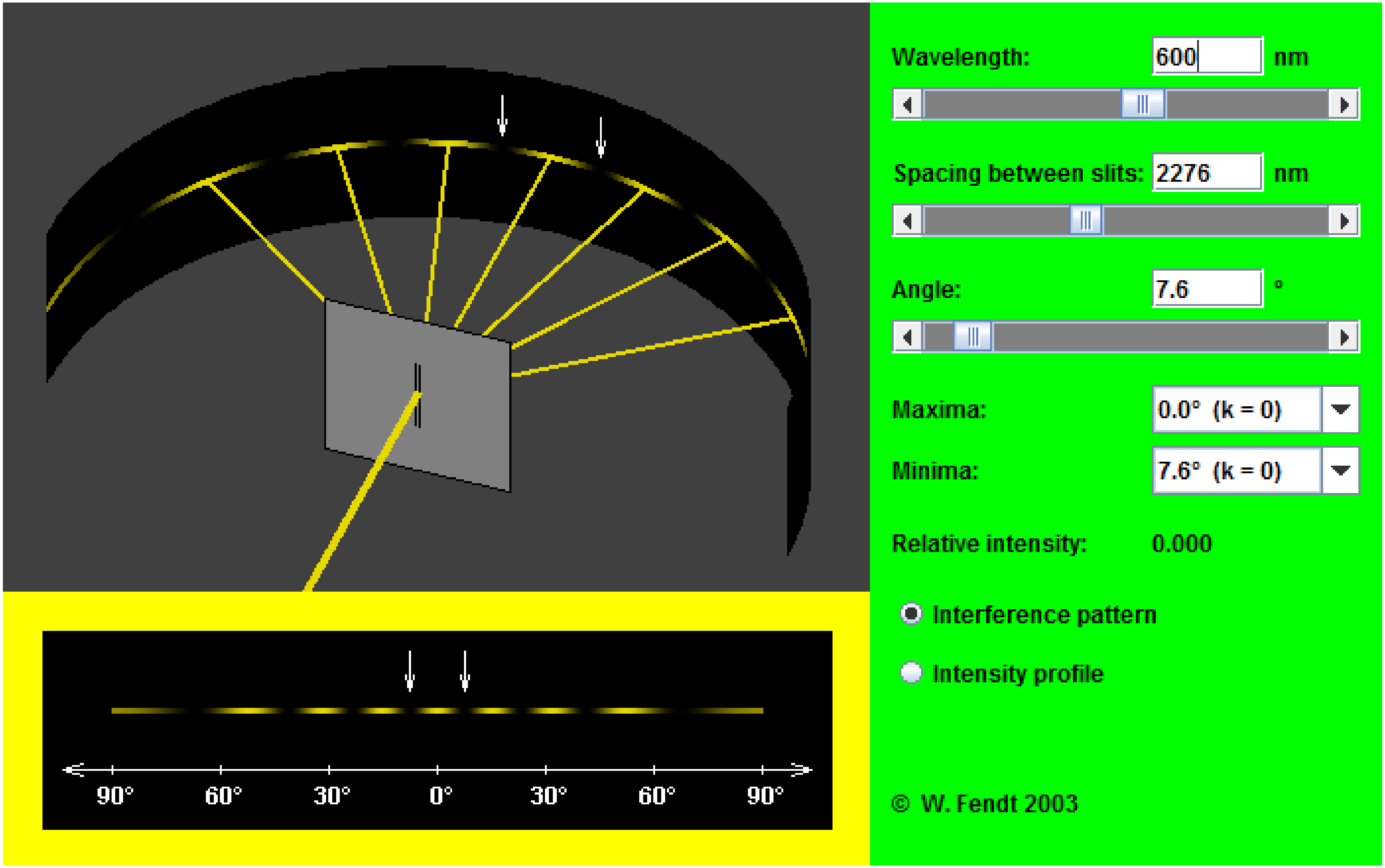
Young’s Double Slit Experiment

- 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.


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
90°
60°
30°
0°
30°
60°
90°

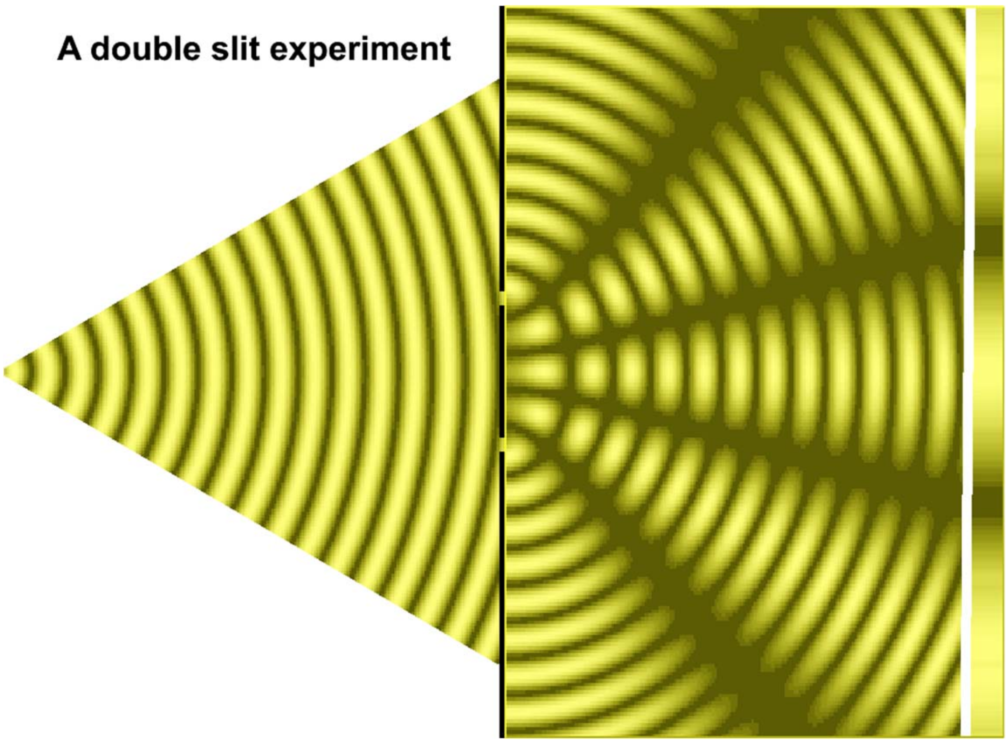


Wavelength:
600
nm
Spacing between slits:
2276
nm
Angle:
7.6
°
Maxima:
0.0° (k = 0)
Minima:
7.6° (k = 0)
Relative intensity:
0.000
Interference pattern
Intensity profile
© W. Fendt 2003
90°
60°
30°
0°
30°
60°
90°

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**.



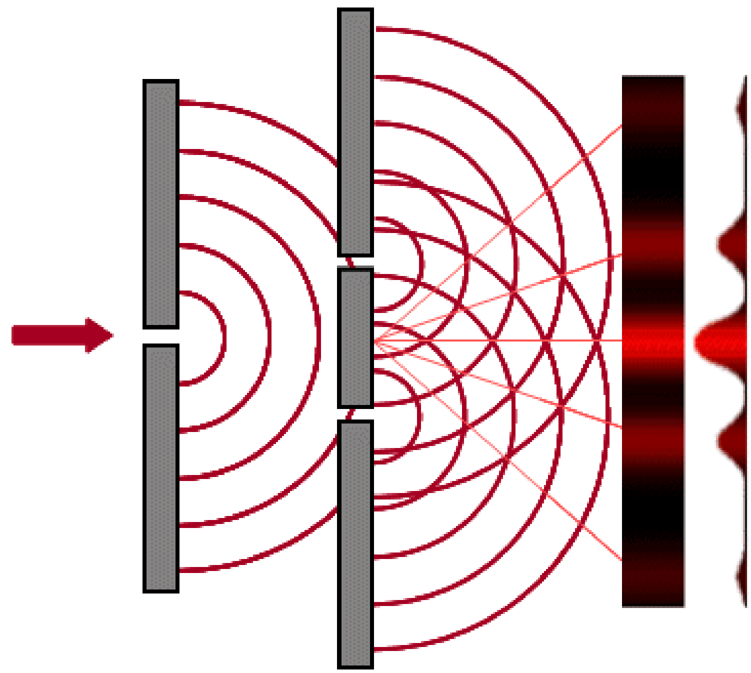
Conditions for Interference

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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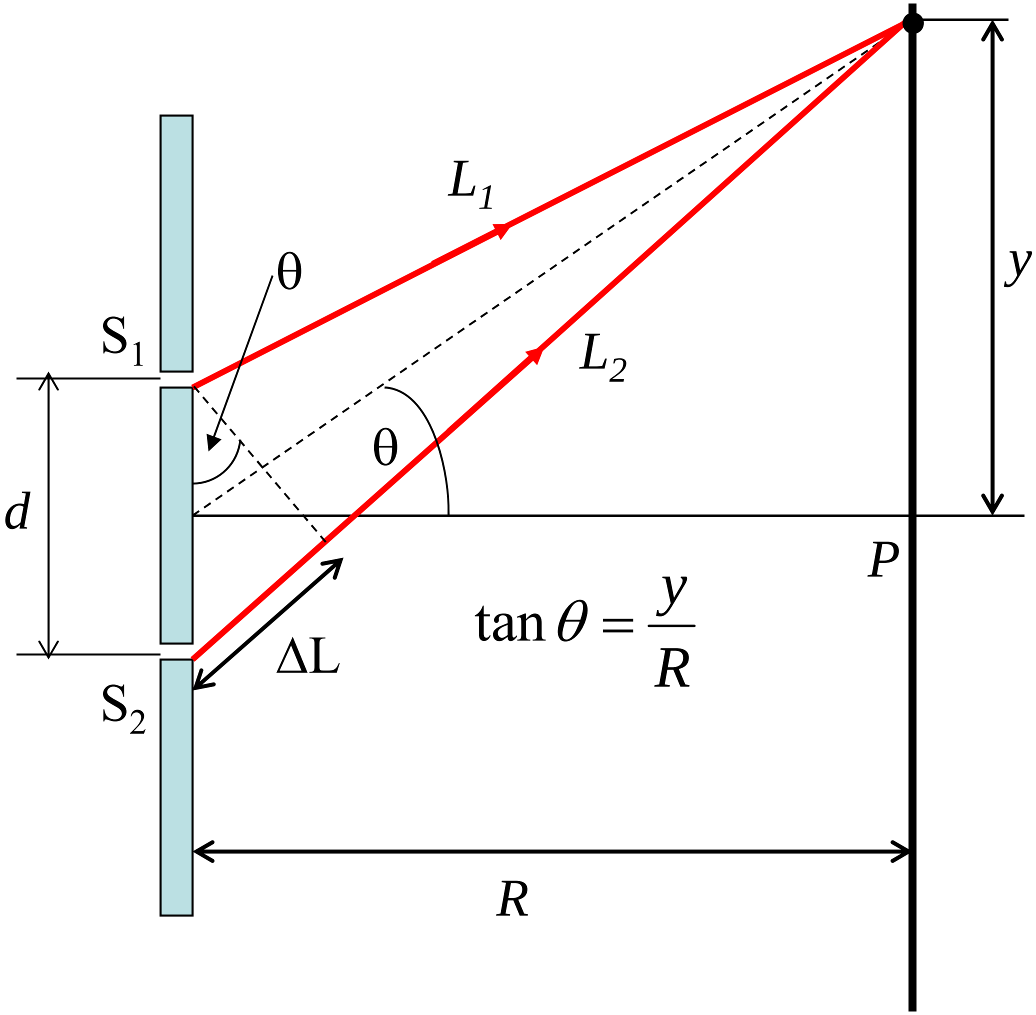
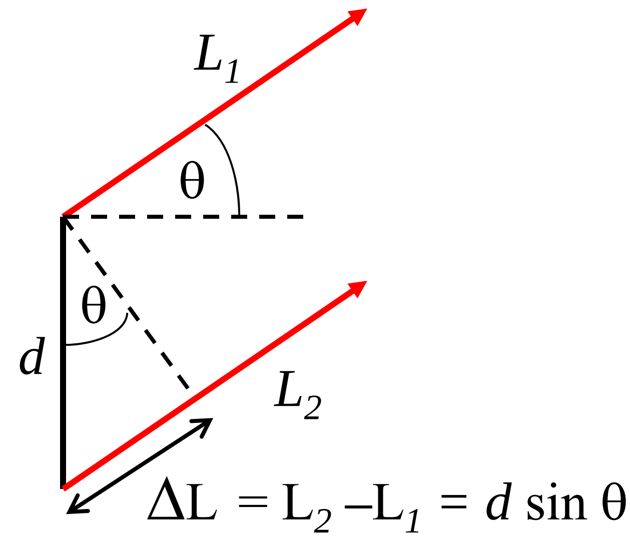
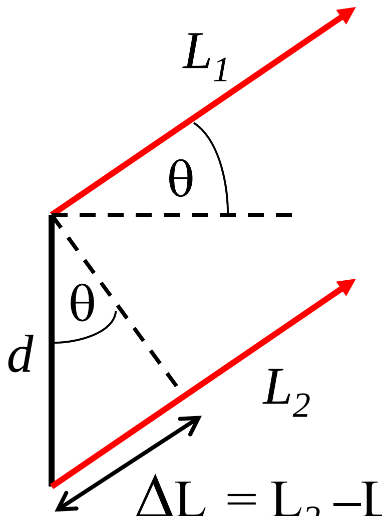


For an infinitely distant* screen:



*so that all the angles labeled θ are approximately equal



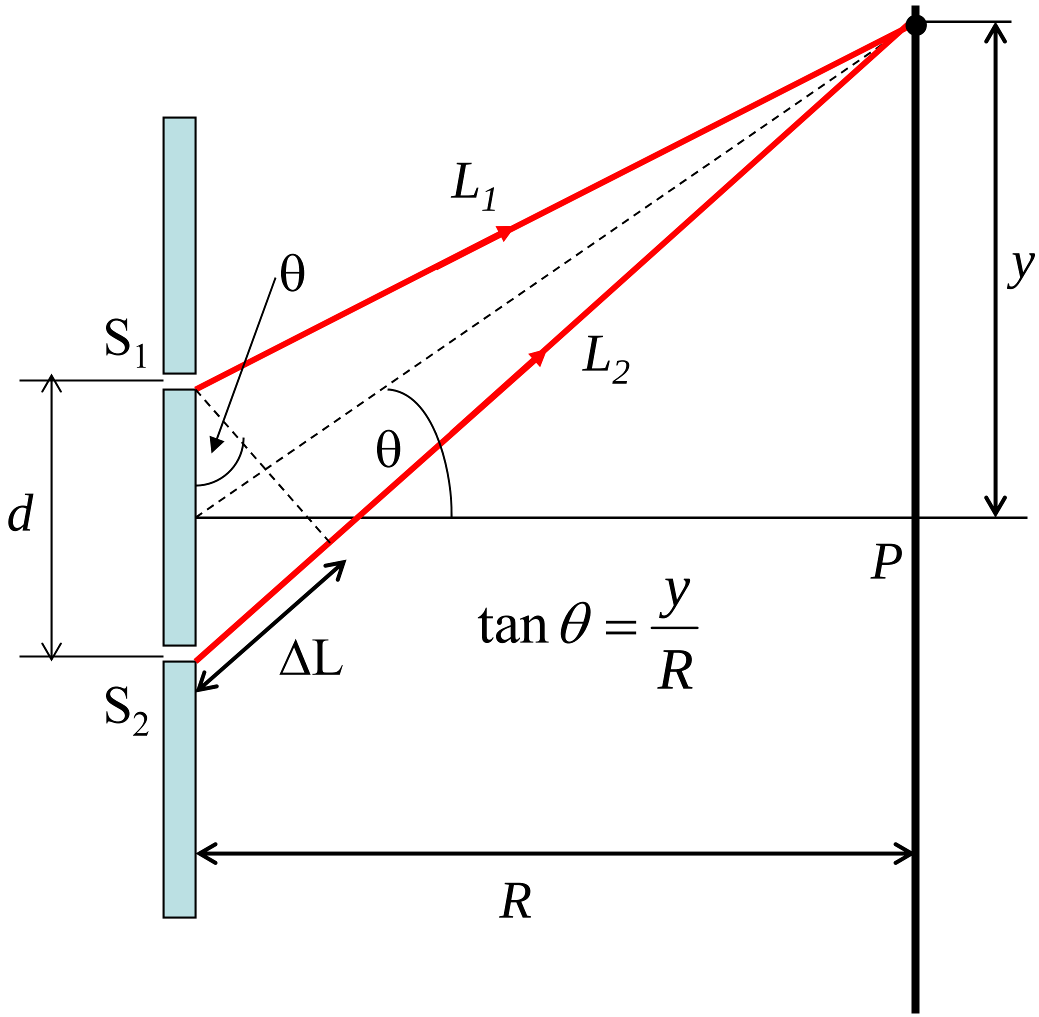
Constructive Interference:

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

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:

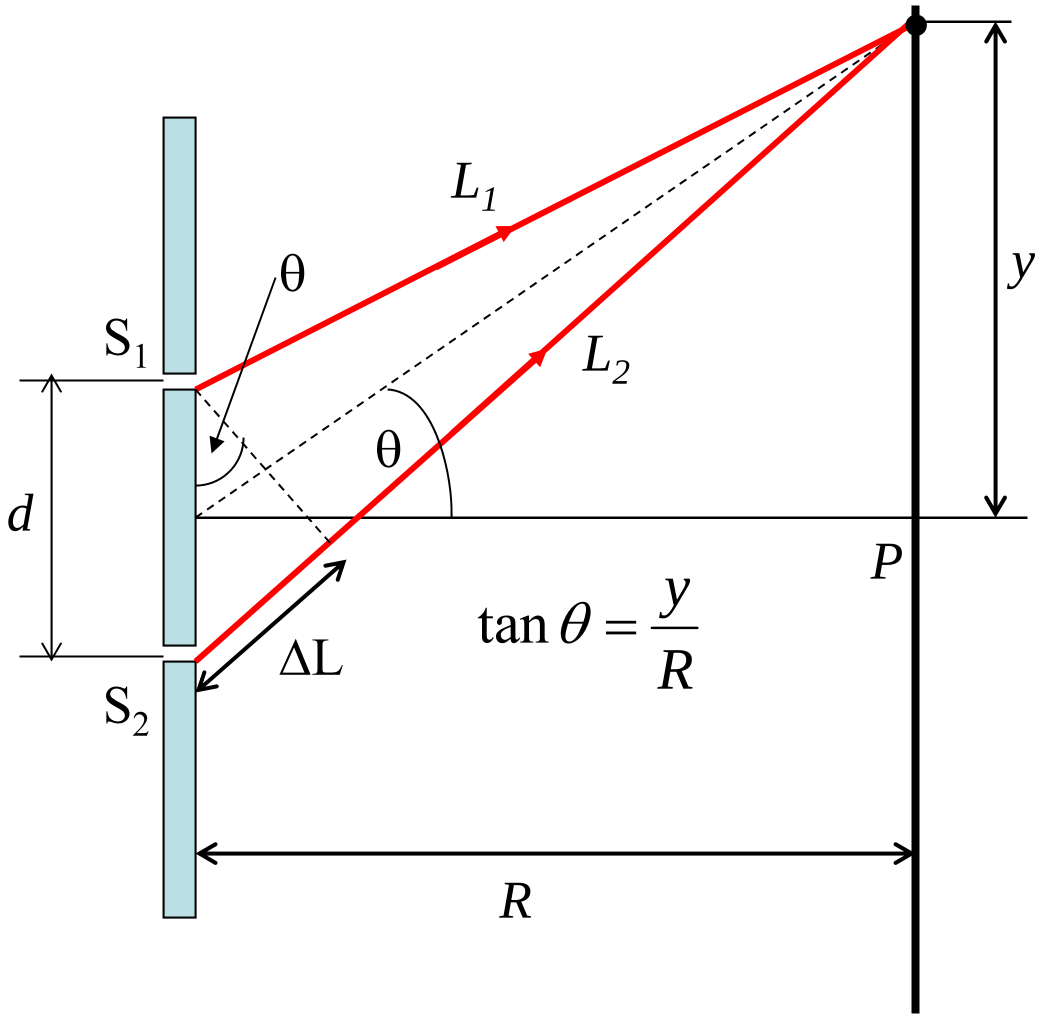
$$m\lambda = d\ \sin\theta$$

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

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

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:

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

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

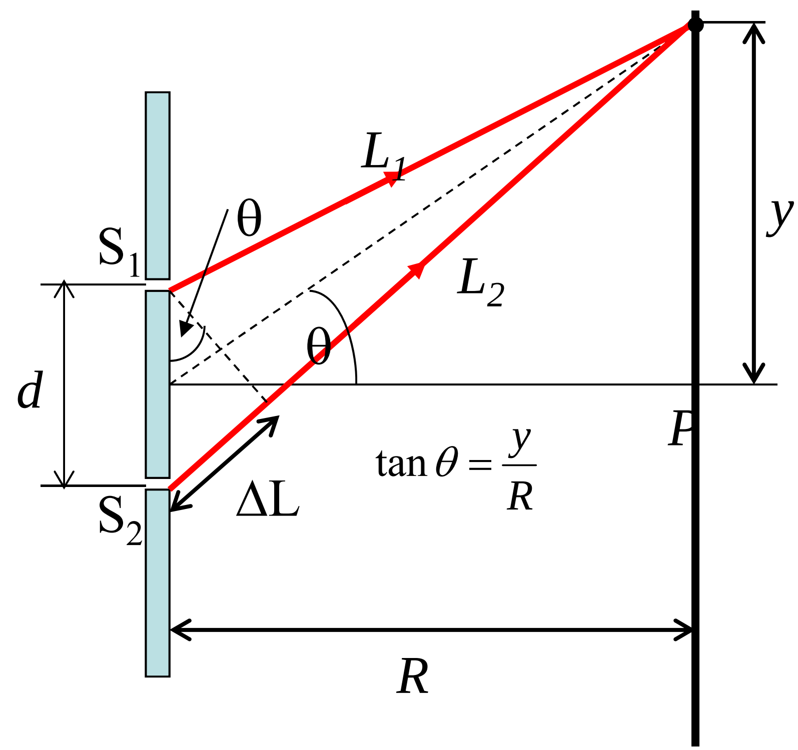
$$y = \frac{\lambda R}{d}\left(m + \frac{1}{2}\right)$$

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:

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

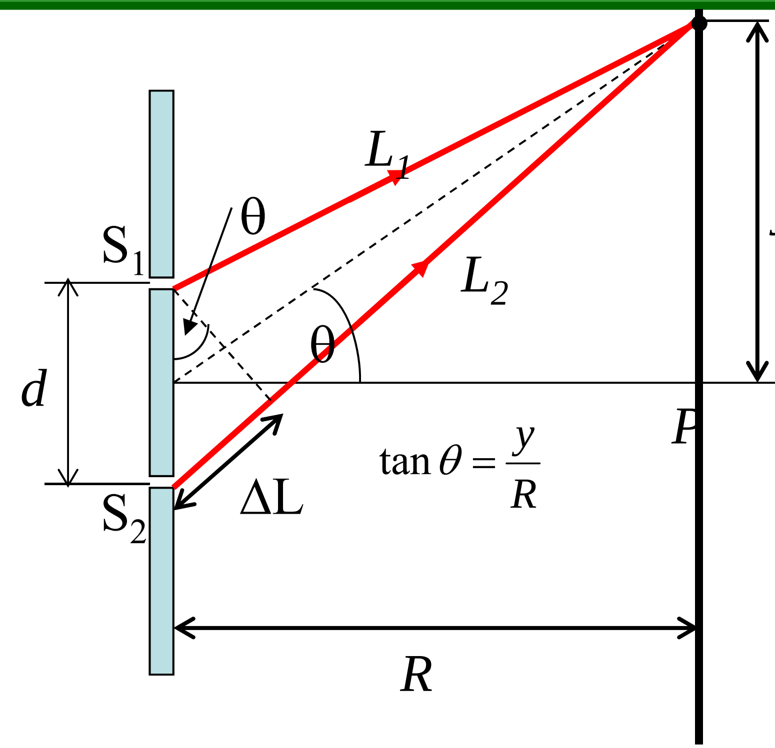
$$m\lambda = d \frac{y}{R}$$

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

$$\lambda = \frac{(4.5 \times 10^{-2} \text{ m})(3.0 \times 10^{-5} \text{ m})}{(1.2 \text{ m})(2)} = 5.6 \times 10^{-7} \text{m} = 560 \text{ nm}$$

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:

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

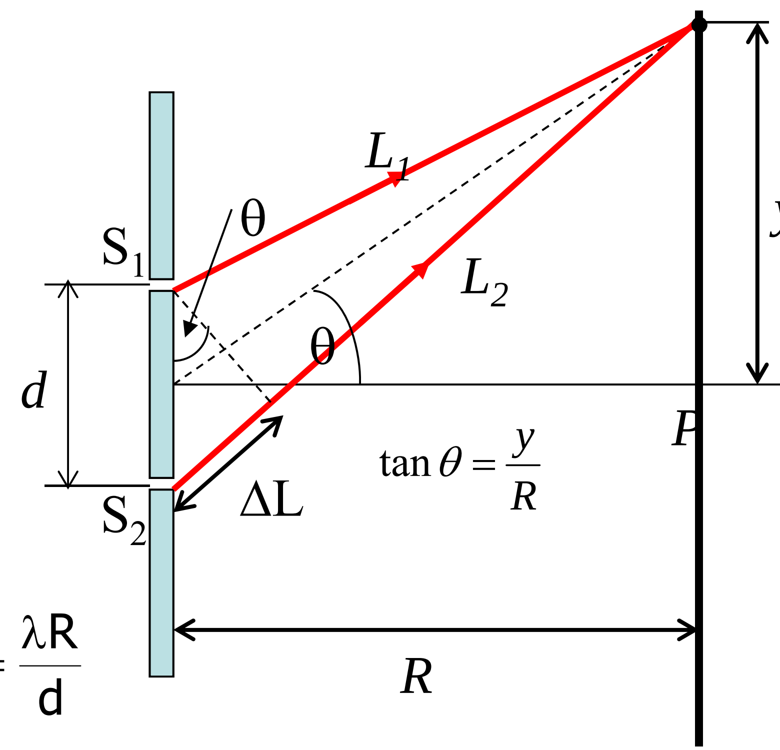
$$m\lambda = d\ \frac{y}{R}$$

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

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

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.



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

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

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

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

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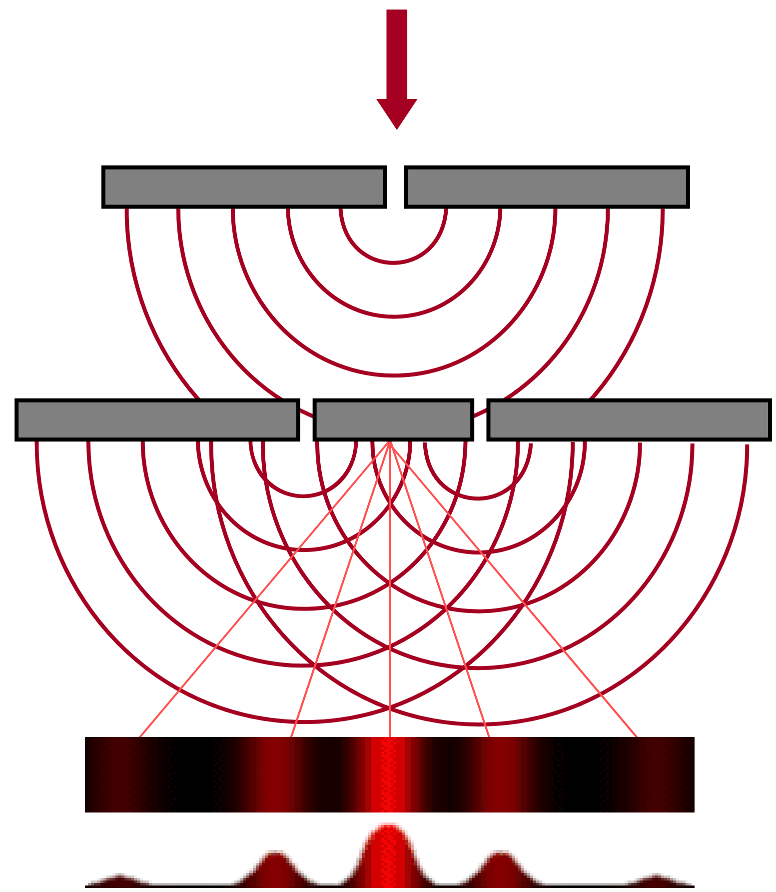
Intensity in the Double Slit Experiment

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)



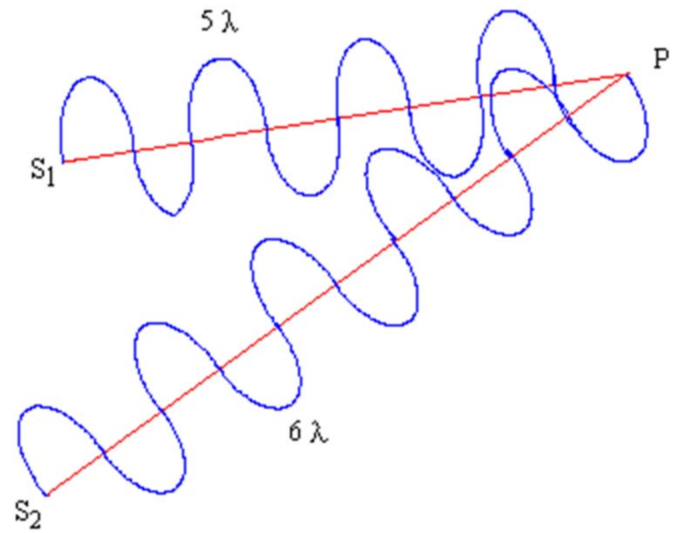
Recall:

- 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"

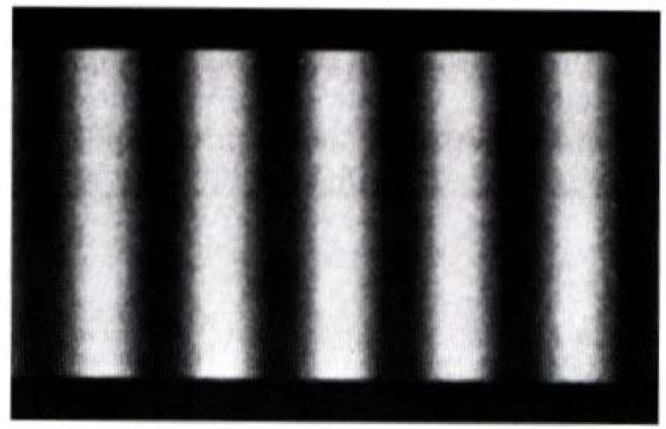
Your text writes the equation for the intensity distribution in the in terms of the phase difference on the previous slide.

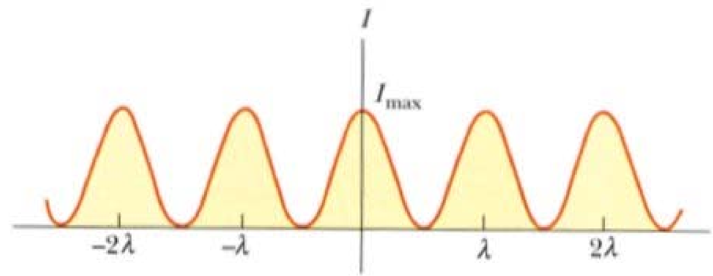
Your starting equation for the intensity is

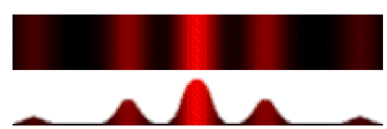
$$I = I_0 \cos^2\left(\frac{\varphi}{2}\right)$$

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?