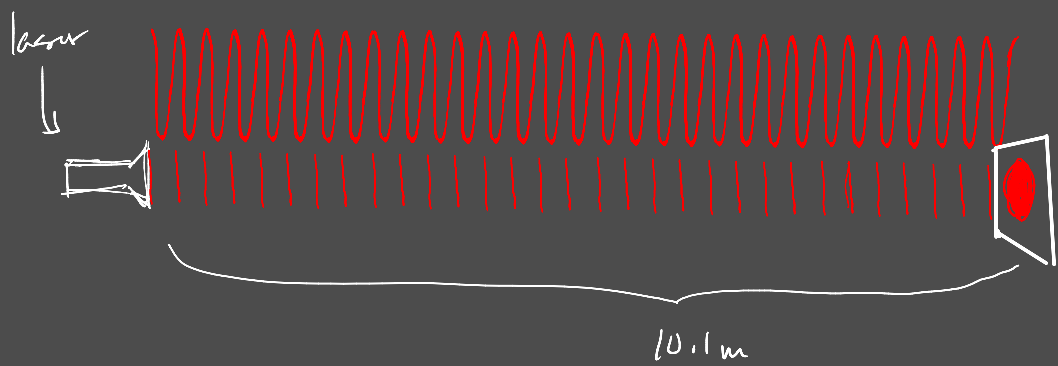
Diffraction and Interference - Chapter 25

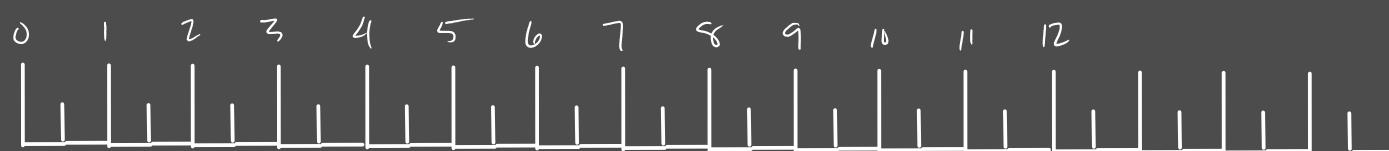
Coherent light - single wavelength
- every part of the beam is "in phase" or lined up with itself



$\lambda = 0.33\ m$

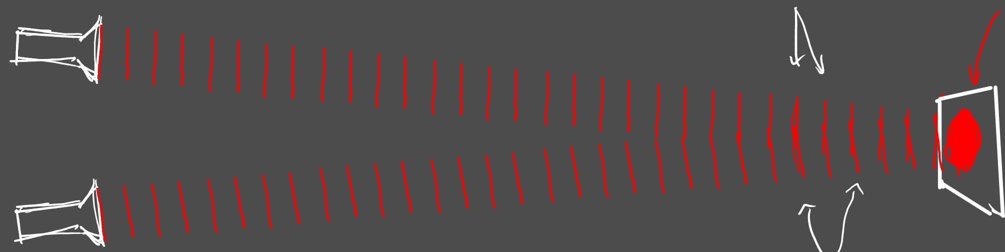
How many λ's fit b/t the laser + the screen?

$$\frac{\text{total distance}}{\text{a wavelength}} = \#\text{ of wavelengths} = \frac{10.1\ m}{0.33\ m} = 30.6 \approx 31 \leftarrow \text{Counted}$$

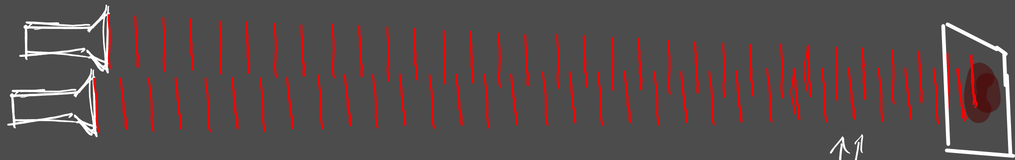


"in phase"

twice as bright



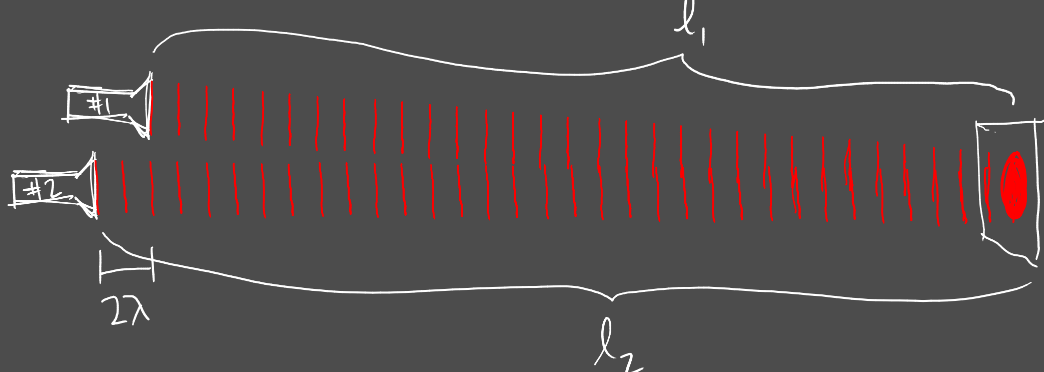
constructive interference



spot on the screen is diminished or totally dark.

"180° out of phase"

destructive interference



constructive interference

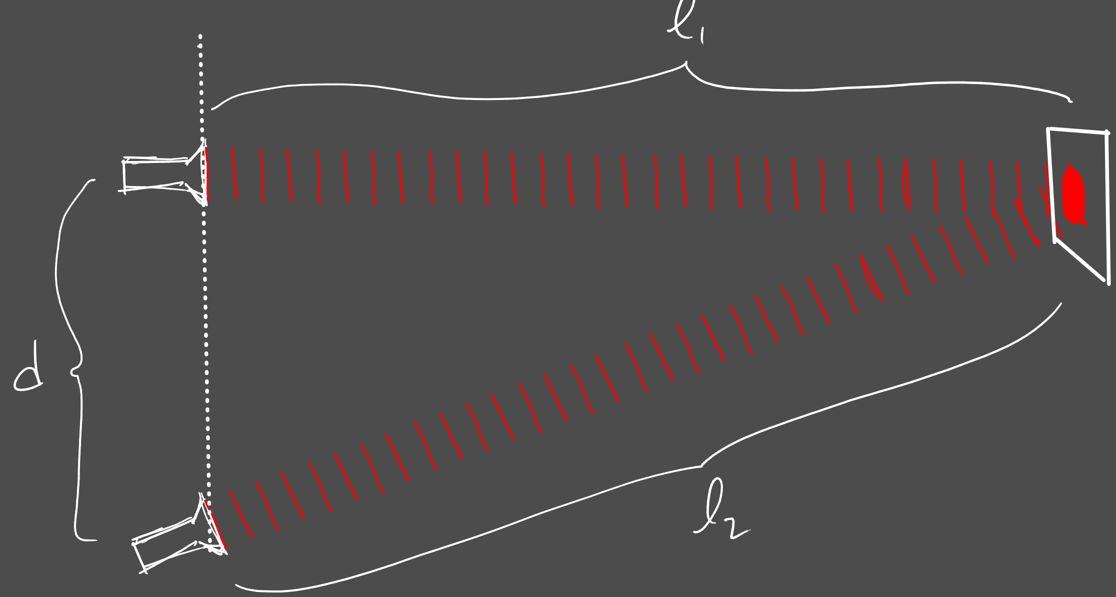
$$\Delta l = l_2 - l_1 = m \cdot \lambda$$

$$m = 0, 1, 2, 3, \ldots$$

destructive interference

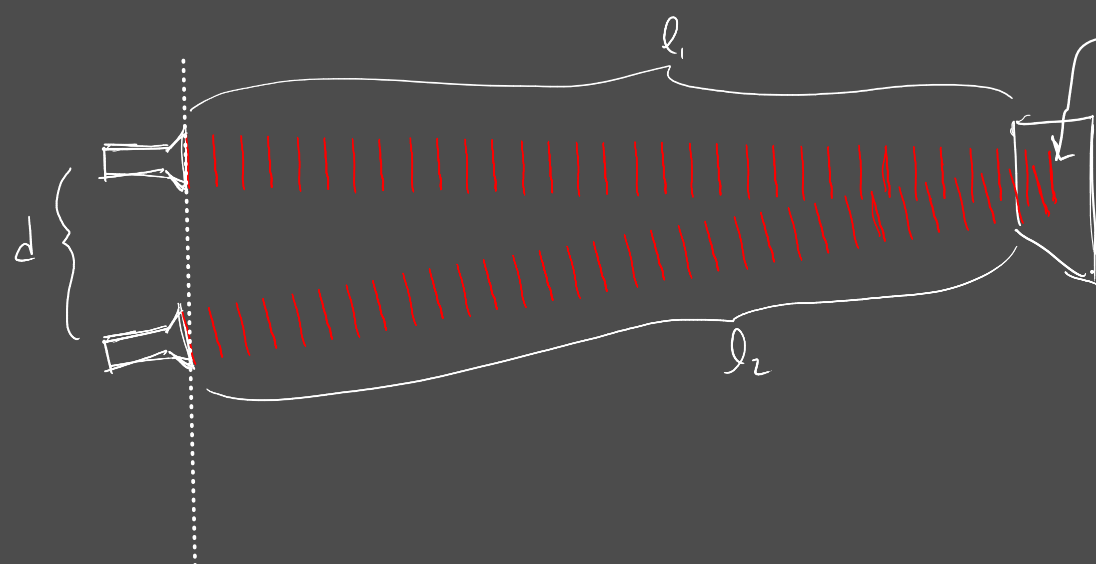
$$\Delta l = l_2 - l_1 = \left(m + \tfrac{1}{2}\right) \cdot \lambda$$

$$m = 0, 1, 2, 3 \ldots$$



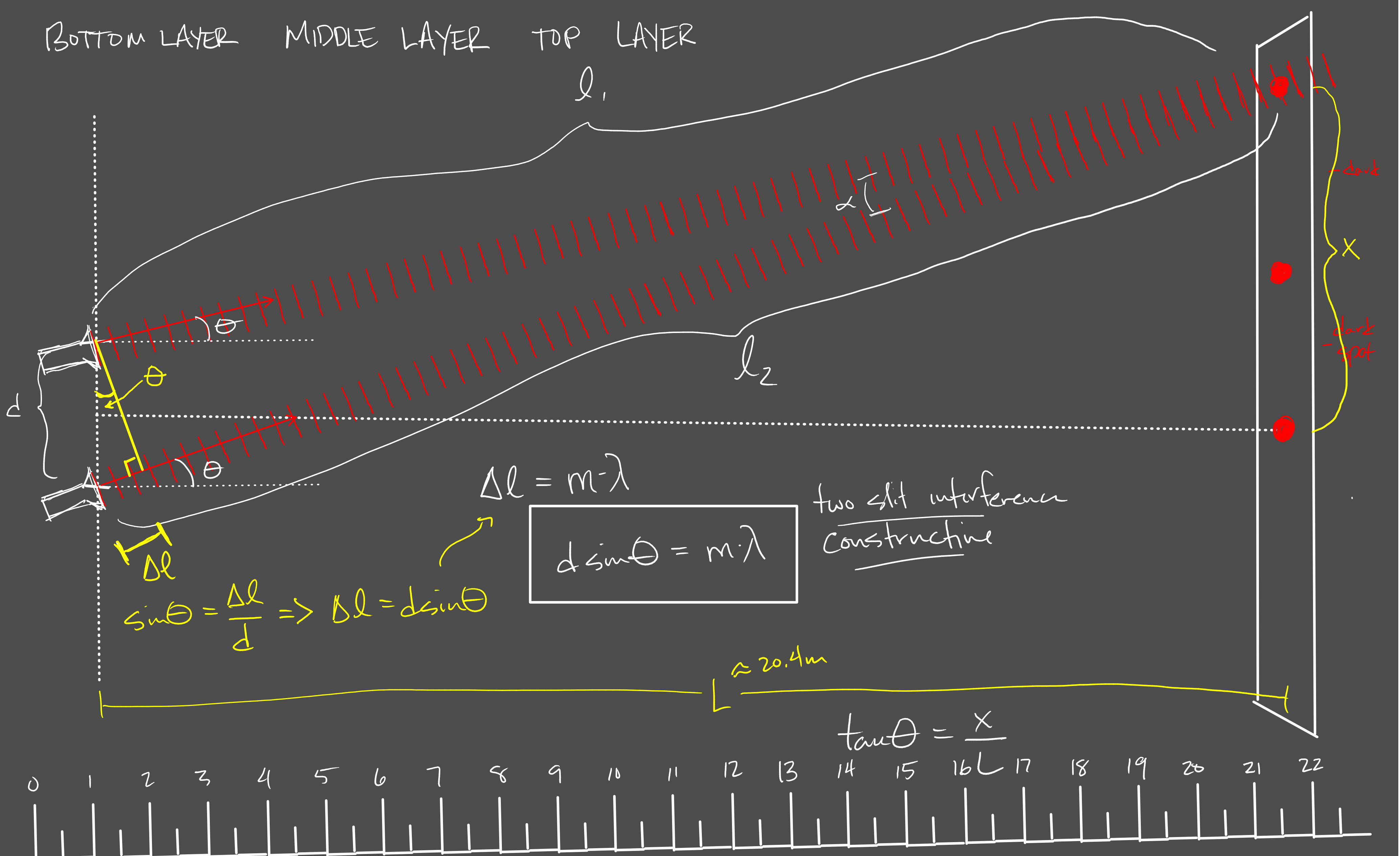
constructive interference

$$l_2 - l_1 = m \cdot \lambda$$



destructive interference

$$l_1 - l_2 = \left(m + \tfrac{1}{2}\right)\lambda$$



$X = L\tan\Theta$

$X = 20.4\tan(15.3^\circ)$

$X = 5.6\ m \approx 5.9\ m$

$\sin\Theta = \frac{m\lambda}{d}$

$\Theta = \sin^{-1}\left(\frac{2\cdot .33m}{2.5m}\right) = 15.3^\circ$

$l_1 = 20.8\ m \qquad l_2 = 21.5$

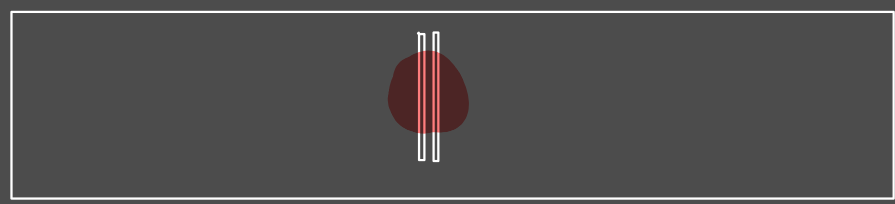
$l_2 - l_1 = 0.7\ m \stackrel{?}{=} 2\cdot\lambda$

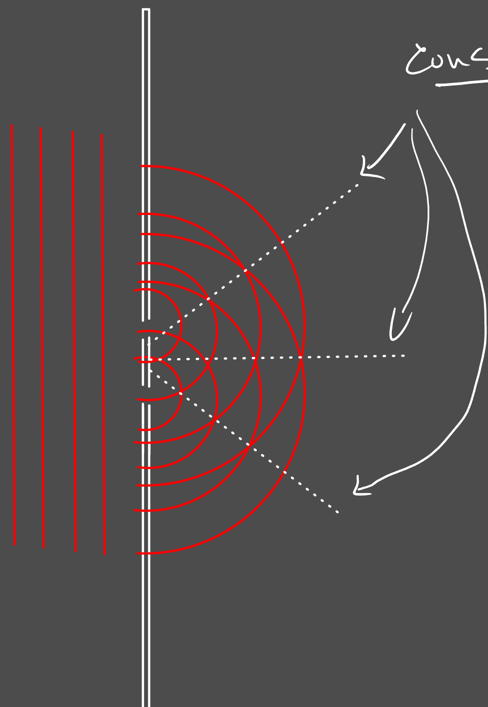
$3\lambda = 1m$

$\lambda = \frac{1}{3}m = .33$

$.7 \approx .67$

double slit





constructive interference

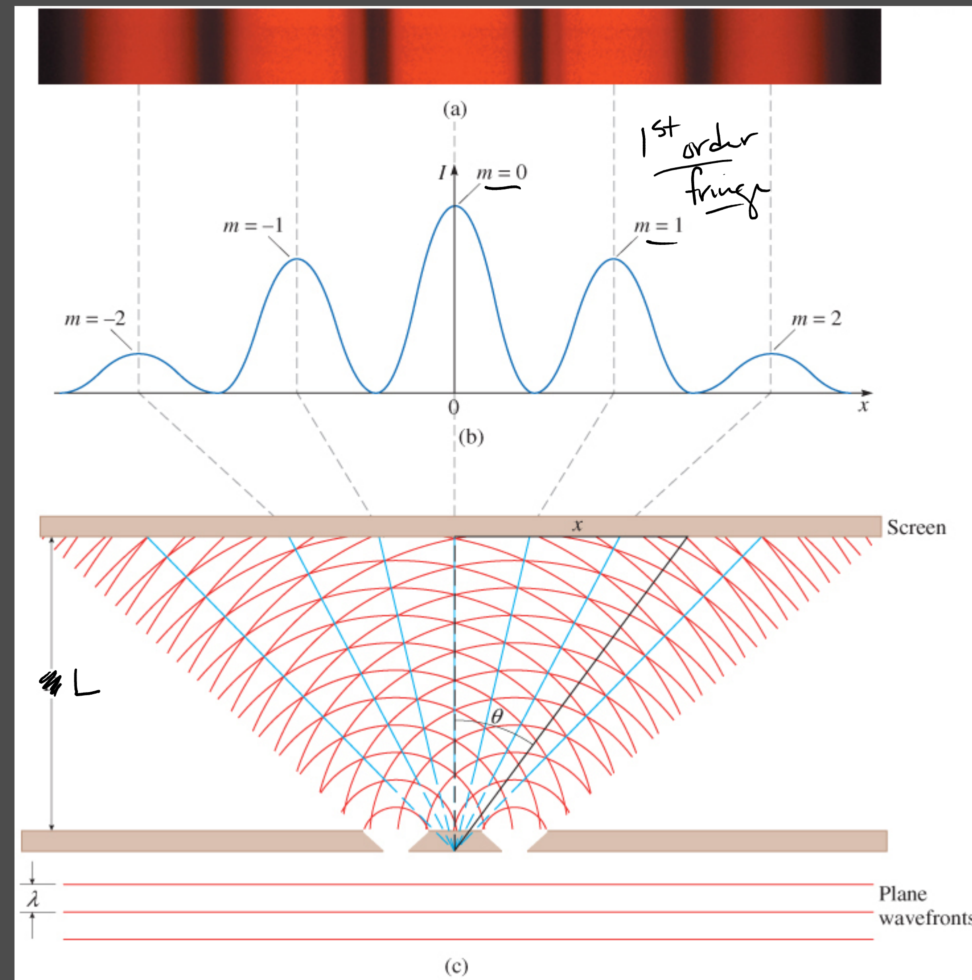
$$d \sin\theta = m\lambda$$

$$\tan\theta = \frac{x}{L}$$

Small angle approximation

When θ is small

$$\tan\theta \approx \sin\theta \approx \theta$$



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

$$\boxed{d \cdot \frac{x}{L} = m\lambda}$$

double slit constructive interference

small angle approximation

In a double-slit interference experiment, the wavelength is 475 nm, the slit separation is 0.120 mm, and the screen is 36.8 cm away from the slits. What is the linear distance between adjacent maxima on the screen? [*Hint:* Assume the small-angle approximation is justified and then check the validity of your assumption once you know the value of the separation between adjacent maxima.] (connect tutorial: double slit 1)

$$\frac{d \cdot x}{L} = m\lambda$$

constants

$$x = \frac{m\,\lambda \cdot L}{d}$$

$m = 0, 1, 2, 3, 4$

$$x_0 = \frac{0 \cdot 475 \cdot 10^{-9}\,\text{m} \cdot (0.368\,\text{m})}{.000120\,\text{m}} = 0$$

$$x_1 = \frac{1 \cdot 475 \cdot 10^{-9}\,\text{m} \cdot (0.368\,\text{m})}{.000120\,\text{m}} = 0.0015\,\text{m}$$

$$x_2 = \frac{2 \cdot 475 \cdot 10^{-9}\,\text{m} \cdot (0.368\,\text{m})}{.000120\,\text{m}} = 0.0030\,\text{m}$$

$\left.\right\}$ 0.0015

$\left.\right\}$ 0.0015

$$\frac{x}{L} = \tan\theta \rightarrow \frac{x}{L} = \sin\theta \rightarrow \frac{x}{L} = \theta$$

in radians

$$\frac{.0015}{.368} = .0041$$

$$\theta = \tan^{-1}(.0041)$$

$$\theta = 0.2335^\circ$$

$$\theta = \sin^{-1}(.0041)$$

$$\theta = 0.2349^\circ$$

$$0.0041\,\text{rad} \cdot \frac{360^\circ}{2\pi\,\text{rad}} = 0.2349$$

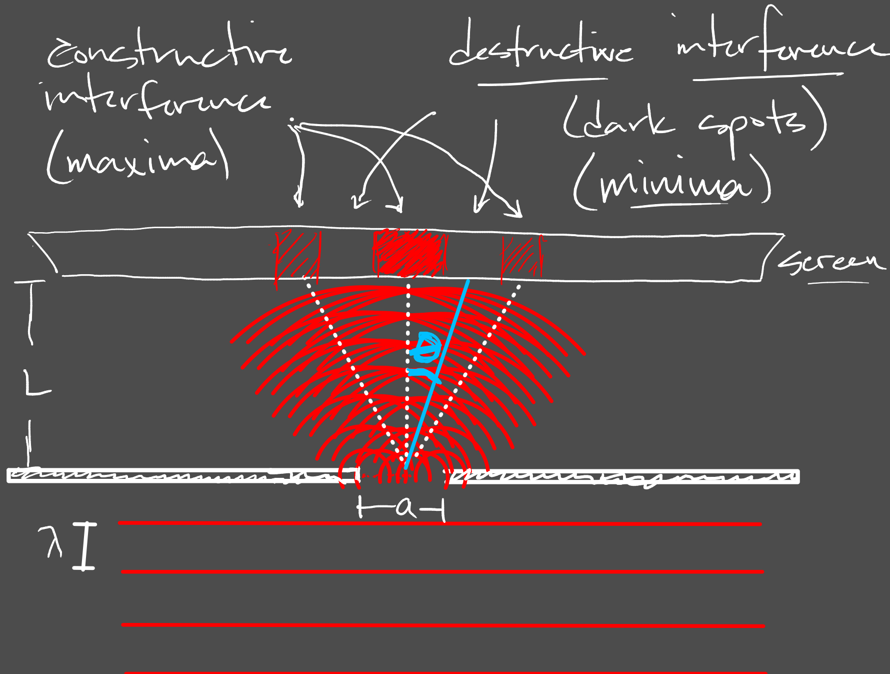
4° $\quad \tan 4^\circ = .0699$

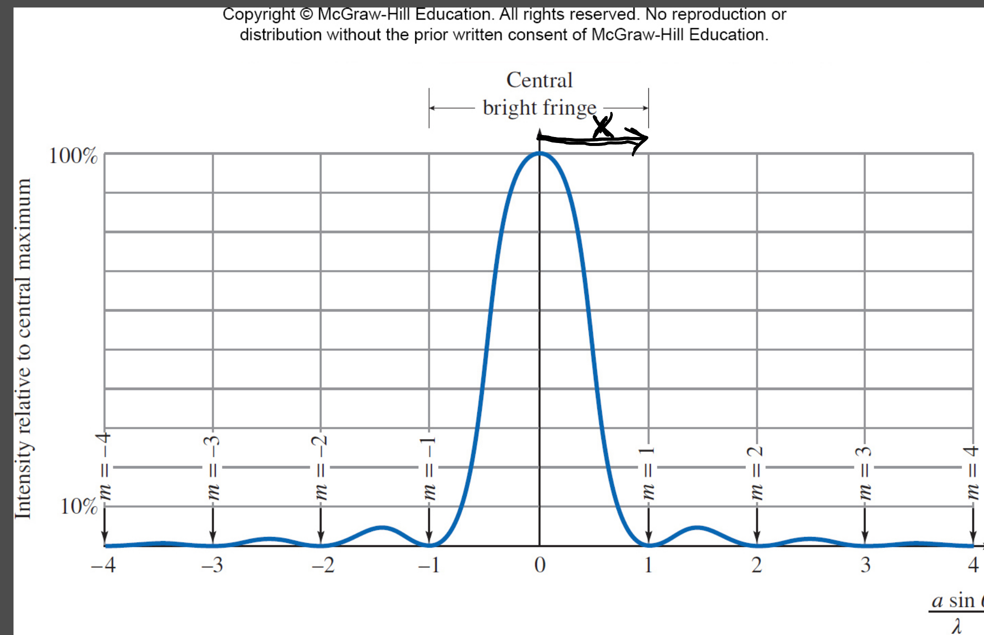
$\sin 4^\circ = .0698$

$$\frac{.0001}{.0699} \cdot 100 = 0.14\%$$

error

Single Slit Diffraction / Interference





This pattern also results from a small obstruction to the light beam

locations of the minima:

$$\boxed{a \cdot \sin\theta = m\lambda}$$

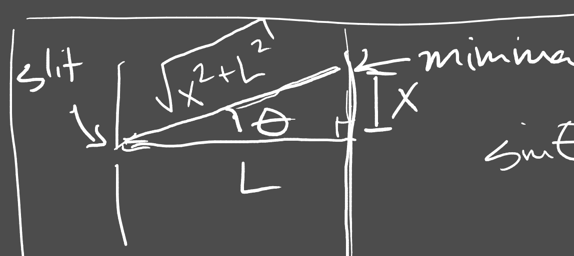
$\sin\theta$ → location from central axis to minima

a → slit width

m → fringe from the center

small angle approximation

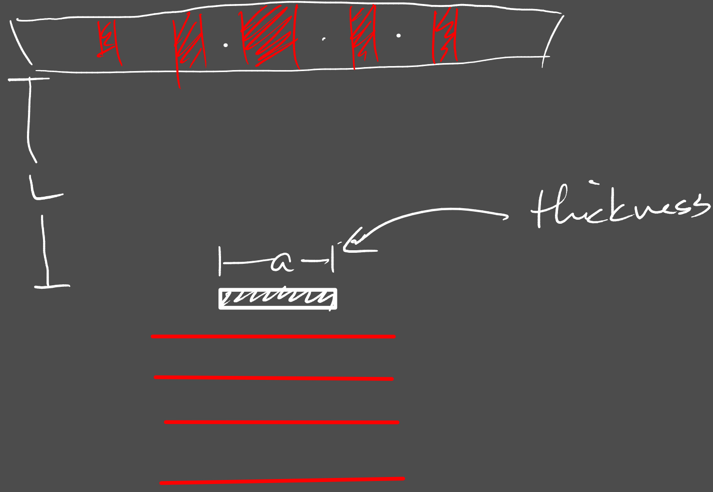
$$\sin\theta = \frac{x}{L} \quad \Big\} \quad \frac{a\,x}{L} = m\lambda$$



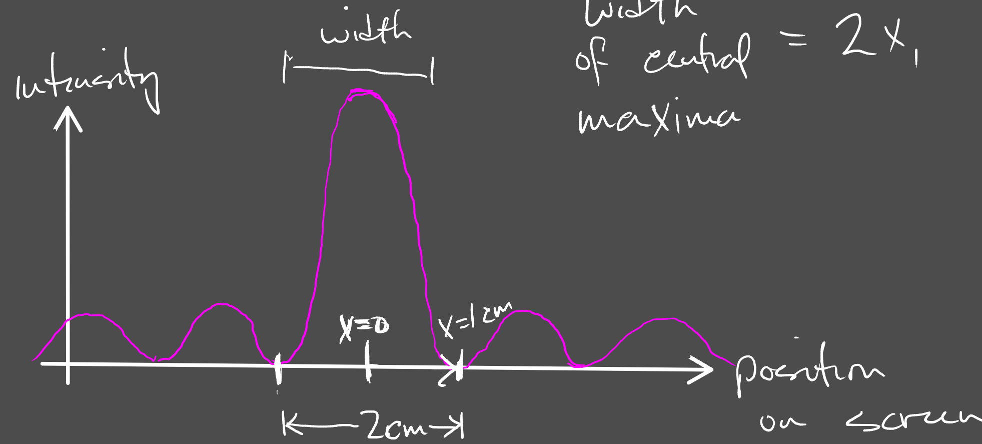
not small angle approximation

$$\sin\theta = \frac{x}{\sqrt{x^2+L^2}}$$

$$\frac{a \cdot x}{\sqrt{x^2+L^2}} = m\lambda$$



The diffraction pattern from a single slit is viewed on a distant screen. Using violet light, the width of the central maximum is 2.0 cm. (a) Would the central maximum be narrower or wider if red light is used instead? (b) If the violet light has wavelength 0.43 μm and the red light has wavelength 0.70 μm, what is the width of the central maximum when red light is used?



width of central maxima $= 2x_1$

$$\frac{ax}{L} = m\lambda$$

from violet to red

$$x = \frac{m\lambda \cdot L}{a}$$

λ increases

400 nm → 700 nm

location of minima

width $\propto x \propto \lambda$

$w \propto x \propto \lambda$

$w \propto \lambda$

$$\frac{W_{red}}{W_v} = \frac{\lambda_{red}}{\lambda_v}$$

$$W_{red} = 2.0\,\text{cm} \cdot \left(\frac{.70\,\cancel{\mu m}}{.43\,\cancel{\mu m}}\right)$$

$$W_{red} = 3.2\,\text{cm}$$