Physics 2C 2/25

1. Models of light
2. Interference (Double-slit): Pattern & Intensity (Idealized)
3. Diffraction Grating
4. Single-Slit Diffraction

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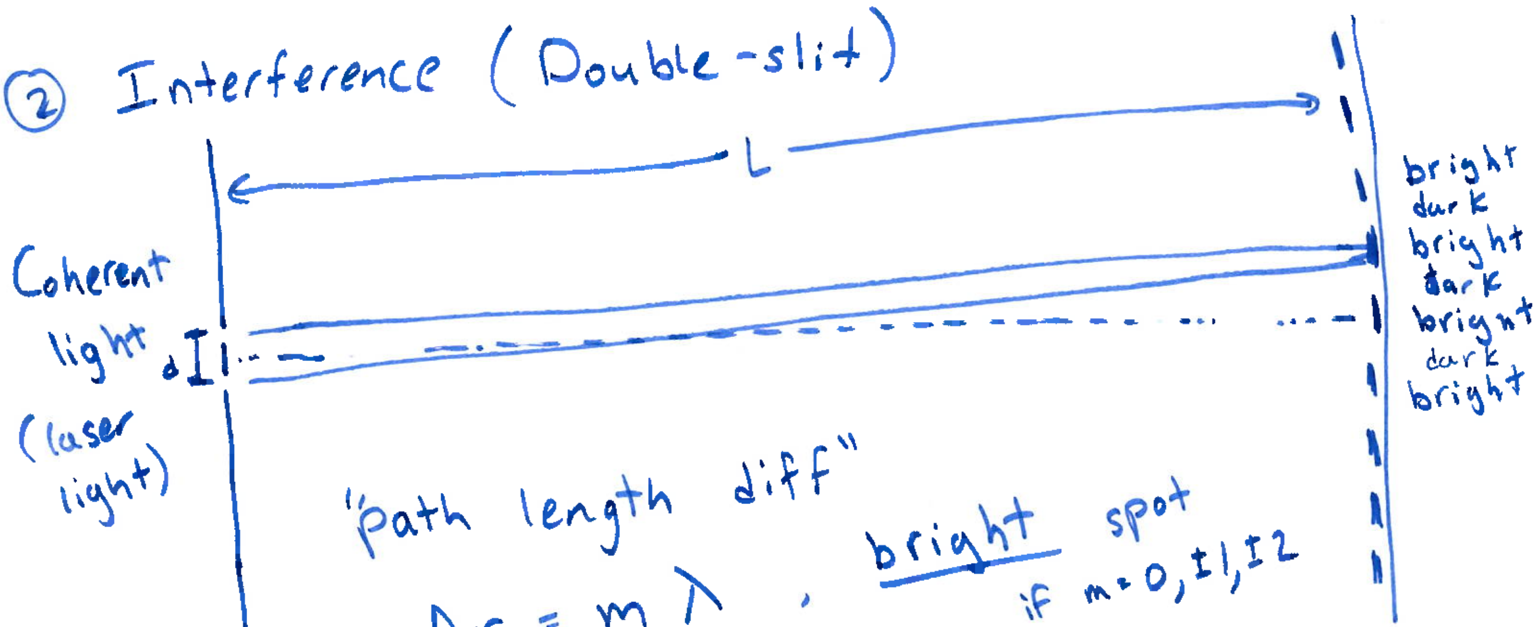
1. Models of light

<u>wave model</u>: EM light waves can disperse & interfere

<u>ray model</u>: light travels in straight lines (mirrors & lenses)

<u>photon model</u>: "packets" of energy (quantized)

2. Interference (Double-slit)



"path length diff"

$\Delta r = m\lambda$, <u>bright</u> spot if $m = 0, \pm 1, \pm 2$

"order"

<u>dark</u> spot if $m = \pm\frac{1}{2}, \pm\frac{3}{2}, \pm\frac{5}{2}, \ldots$

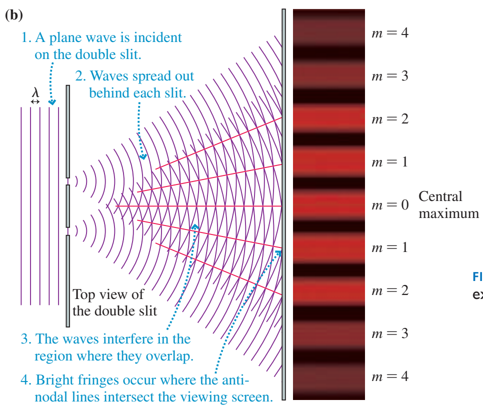


FIGURE 33.5 Geometry of the double-slit experiment.

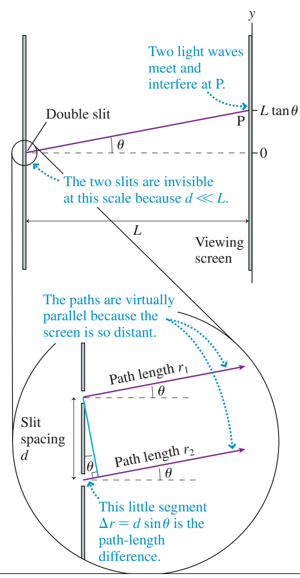


FIGURE 33.6 Intensity of the interference fringes in a double-slit experiment.

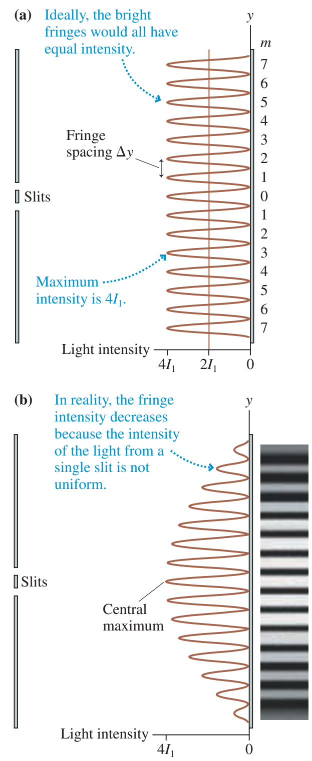


FIGURE 33.7 Top view of a diffraction grating with $N = 10$ slits.

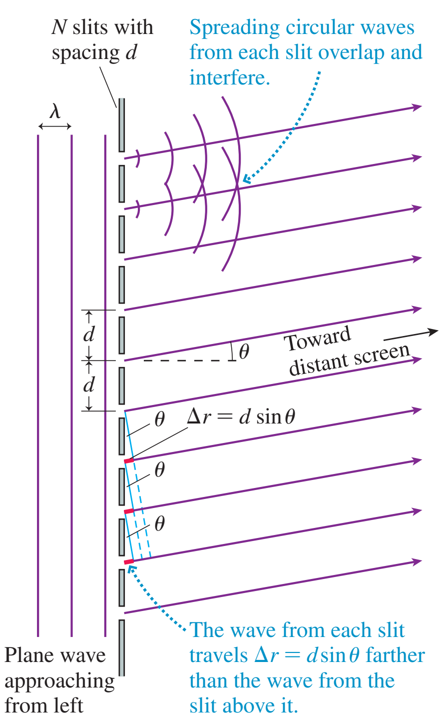
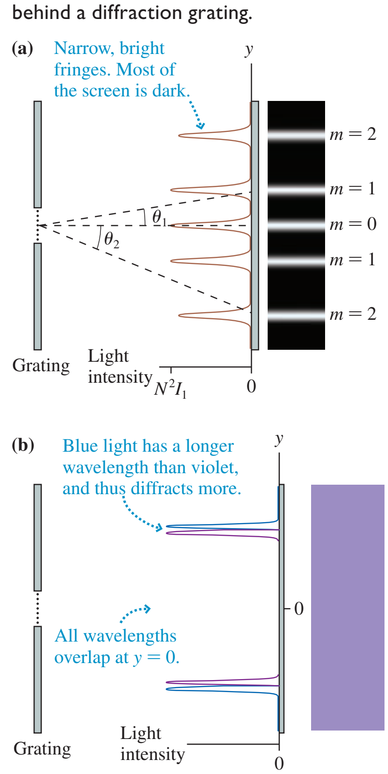


FIGURE 33.9 The interference pattern behind a diffraction grating.

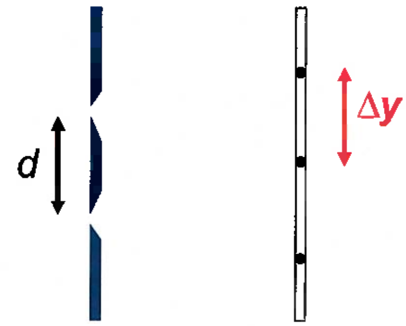


$$d\sin\theta_m = m\lambda = \frac{d\,y_m}{L}$$

A double-slit interference pattern is produced on a screen using monochromatic light of wavelength 600 nm. What will happen to the separation of the interference fringes (Δy) if you decrease the separation of the two slits $\boldsymbol{d}$?

L

$$m\lambda = \frac{\downarrow d\,\Delta y \uparrow}{L}$$



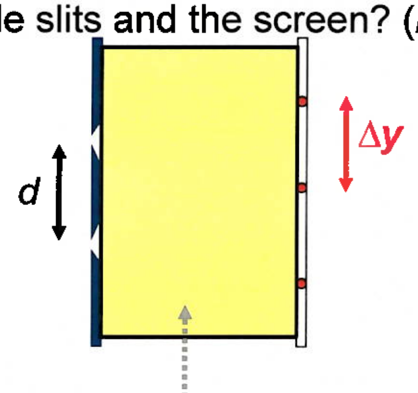
1. Δy will increase
2. Δy will decrease
3. Δy will stay the same
4. Can't be determined

$= \lambda' f$

v? λ? f? $v' = \frac{c}{n}$ $\lambda' = \frac{c}{nf} = \frac{\lambda}{n}$

A double-slit interference pattern is produced on a screen using monochromatic light of wavelength 600 nm. What will happen to the separation of the interference fringes (Δy) if you put a tank of kerosene between the double slits and the screen? ($n_{kerosene} > 1$)

$$m\lambda\downarrow = \frac{d\,\Delta y\downarrow}{L}$$

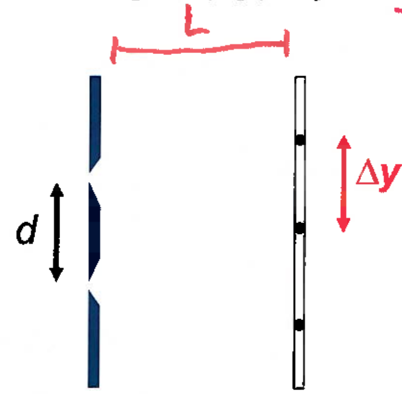


A tank of kerosene

1. Δy will increase
2. Δy will decrease
3. Δy will stay the same
4. Can't be determined

$d \sin\theta_m = m\lambda \Rightarrow \frac{d\,\Delta y}{L} = \lambda$

A double-slit interference pattern is produced on a screen using monochromatic light of wavelength 600 nm. What will happen to the separation of the interference fringes (Δy) if you decrease the separation of the two slits ***d*** ?



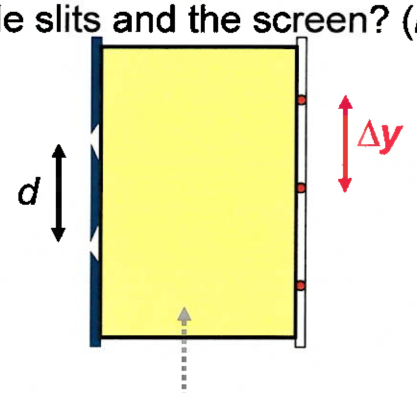
1. Δy will increase
2. Δy will decrease
3. Δy will stay the same
4. Can't be determined

$v' = \frac{c}{n} = \lambda' f \Rightarrow \lambda' = \frac{c}{nf} = \frac{\lambda}{n}$

A double-slit interference pattern is produced on a screen using monochromatic light of wavelength 600 nm. What will happen to the separation of the interference fringes (Δy) if you put a tank of kerosene between the double slits and the screen? ($n_{kerosene} > 1$)

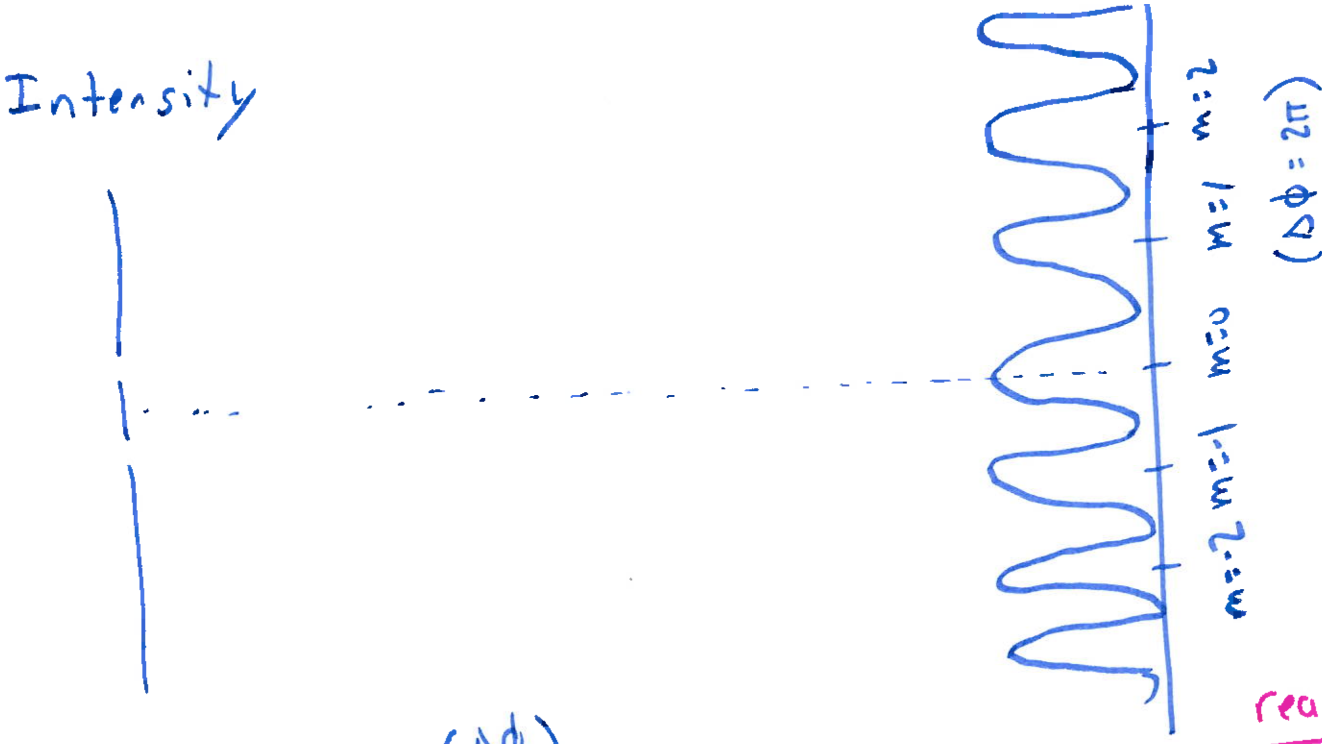
$\frac{d\,\Delta y'}{L} = \lambda' = \frac{\lambda}{n}$

$\Rightarrow \Delta y' = \frac{\Delta y}{n}$



A tank of kerosene

1. Δy will increase
2. Δy will decrease
3. Δy will stay the same
4. Can't be determined



reality: there's an envelope

$$I_{double} = I_{max}\cos^2\left(\frac{\Delta\phi}{2}\right)$$

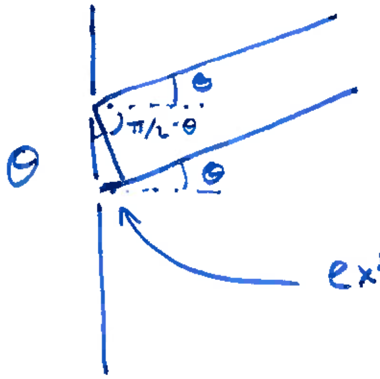
Note: "phase diff" vs. "path length" diff

$$\boxed{\Delta\phi = 2\pi\frac{\Delta r}{\lambda}} = 2\pi\frac{d\sin\theta}{\lambda}$$

$$\approx \frac{2\pi d\tan\theta}{\lambda} = \frac{2\pi d}{\lambda L}y$$

(Ch. 17) : $E = \left|2e\cos\left(\frac{\Delta\phi}{2}\right)\right|$ $\qquad (I_1 = ce^2)$

$$I_{double} = 4I_1\cos^2\left(\frac{\pi d}{\lambda L}y\right)$$



extra distance

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

small θ $\Rightarrow$ $\sin\theta \approx \theta \approx \tan\theta$

$$\Rightarrow \boxed{\theta_m = m\frac{\lambda}{d}}$$

What about position?

$$y = L\tan\theta \approx L\theta$$

$$\boxed{y_m = \frac{m\lambda L}{d}} \qquad \Delta y = \frac{\lambda L}{d}$$

~~[illegible]~~

Demo

$\Delta y =$ ~~[illegible]~~ 1 cm

green ($\lambda = 540\,\text{nm}$)

$L =$ ~~[illegible]~~ 1.5m

what is double slit distance d?

$$d = \frac{\lambda L}{\Delta y} = \text{~~[illegible]~~}$$

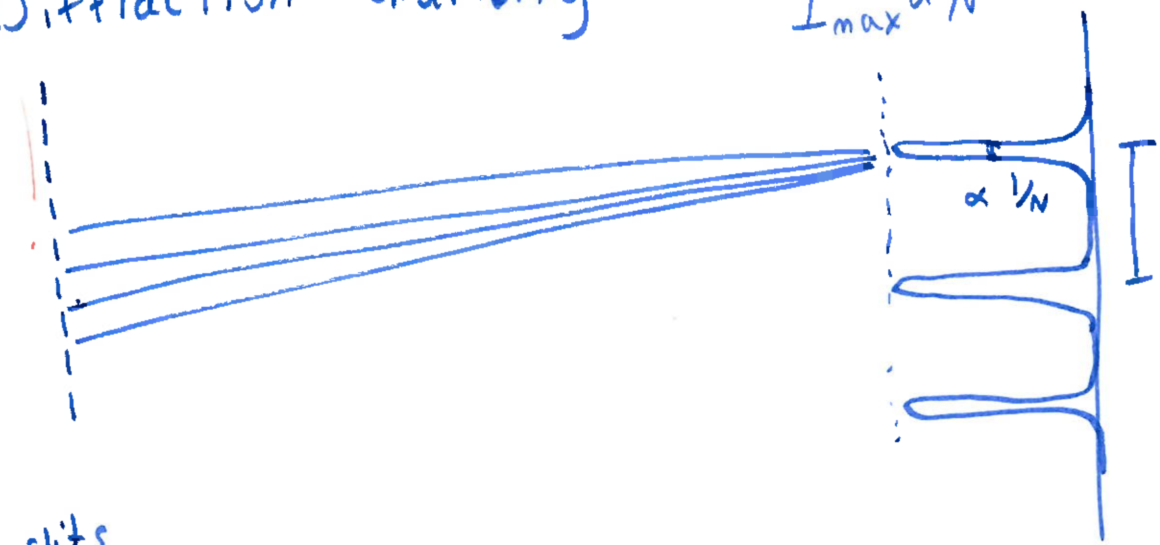
$$= \frac{(540\,\text{nm})(1.5\,\text{m})}{1\,\text{cm}}$$

$$= \boxed{81\,\mu\text{m}}$$

Actual: ~~[illegible]~~ 0.8 mm ✓

(3) Diffraction Grating

$I_{max} \propto N^2$



$d \sin\theta_m = m\lambda$

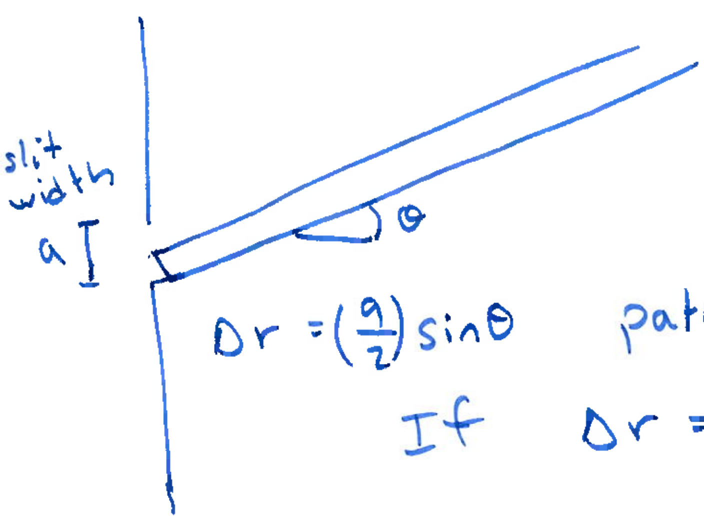
also works for diff. grating

N slits
spacing d
"diffraction grating"

Note: In this case the pattern is a result of interference of many different "sources" of light

(4) Single slit Diffraction : Now consider slit of finite extent.

Huygen's principle: all points along the wave front are sources of spherical waves



$\Delta r = \left(\frac{a}{2}\right)\sin\theta$ path-length diff.

If $\Delta r = \frac{\lambda}{2} = \frac{a}{2}\sin\theta$ destructive

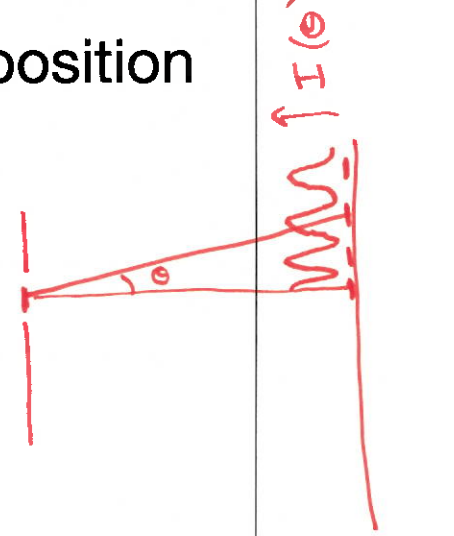
$\Rightarrow a\sin\theta_p = p\lambda$ $\quad p = \pm 1, \pm 2, \pm 3, \ldots$

(no $p=0$) (dark fringes)

path length diff : $\boxed{\Delta r = d\sin\theta = m\lambda}$ if $m = 0, \pm 1, \pm 2, \ldots$ bright

if $m = \pm\frac{1}{2}, \pm\frac{3}{2}, \ldots$ dark

Which of the following could be the intensity $I(\theta)$ where θ labels the position on a screen?



units!

A) ~~$I_{\max}\cancel{\theta}\cos^2(d\sin\theta)$~~

B) ~~$I_{\max}\cancel{\theta}\cos^2(2d\sin\theta)$~~

plug in $m=\frac{1}{2}$

C) $I_{\max}\cancel{\theta}\cos^2\left(\dfrac{\pi d\sin\theta}{\lambda}\right)$ $\quad$ $I_{max}\cos^2\left(\frac{\pi m}{2}\right) = 0$

D) $I_{\max}\cancel{\theta}\cos^2\left(\dfrac{2\pi d\sin\theta}{\lambda}\right)$ $\quad$ $I_{max}\cos^2\left(\frac{2\pi m}{2}\right) = I_{max}$

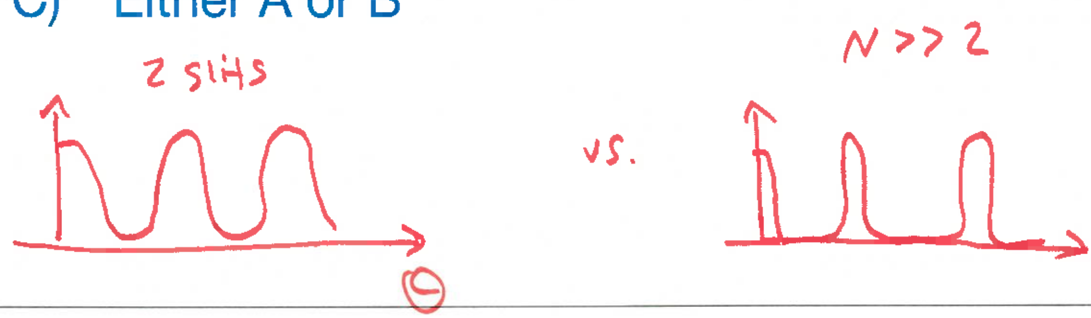
E) None of the above

Which of the following physical situations could $I(\theta)$ represent? $\quad I(\theta) = I_{max}\cos^2\left(\frac{\Delta\phi}{2}\right)$

A) Interference pattern produced by 2 slits

B) Interference pattern produced by 1000 slits

C) Either A or B



yellow ~580 nm
red ~650 nm

$\frac{d \Delta y_n}{L} = \lambda \uparrow$

46 The figure below shows two diffraction patterns. The top one was made with yellow light, and the bottom one with red. Could the slits used to make the two patterns have been the same?

red should have wider
more separated pattern

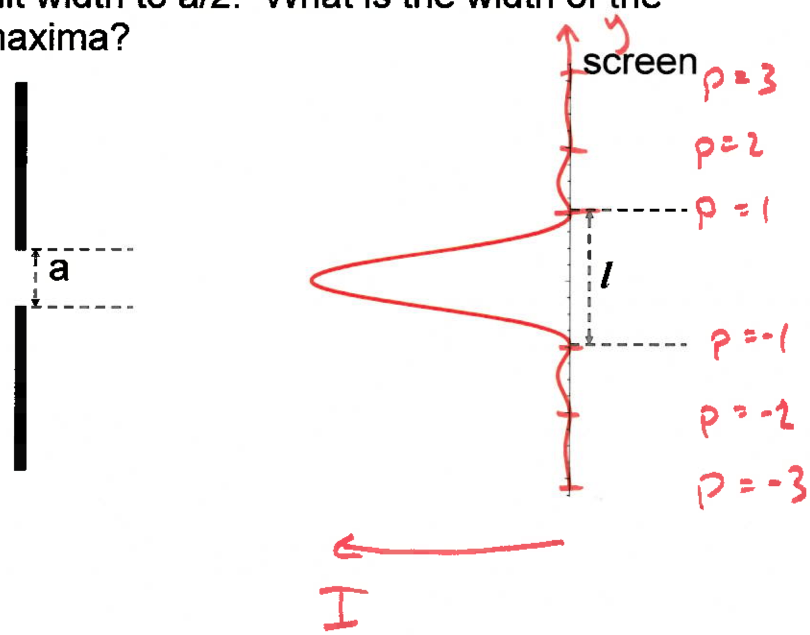
A) Yes
B) No

A single slit of width a is illuminated by light of wavelength λ, so that the width of the central diffraction maxima is *l*. Now you decrease the slit width to a/2. What is the width of the central diffraction maxima?

diff. minima

$a \sin\theta = p\lambda$

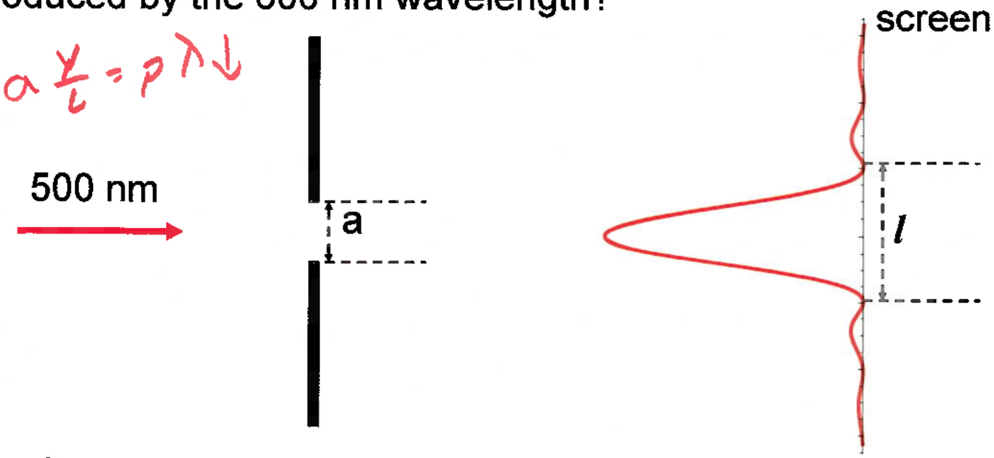
$\downarrow a \frac{y \uparrow}{L} = p\lambda$



1. *l*/2
2. 2*l*
3. *l*/4
4. 4*l*
5. *l*

This time you keep the same slit width, but use another monochromatic light of wavelength 500 nm. How does the broadness of the central bright fringe change compared to that produced by the 600 nm wavelength?

$a\frac{y}{L} = p\lambda\downarrow$



1. Increases
2. Decreases
3. Stays the same
4. Depends on the exact value of the slit width

Calculate l for 500 nm

$$l = 2\Delta y = \frac{2\lambda L}{a} = \frac{(1\,\mu m)(3\,m)}{10\,\mu m} = \boxed{0.3\,m}$$