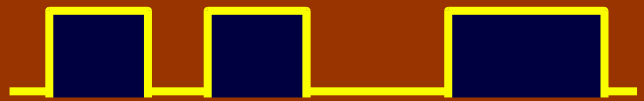
# *ConcepTest 24.1* Superposition

If waves A and B are superposed (that is, their amplitudes are *added*) the resultant wave is

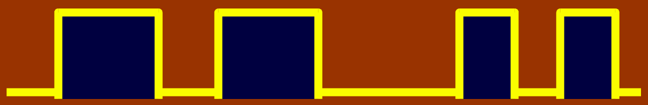
A

B

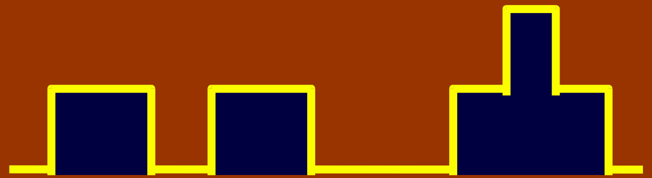
1)



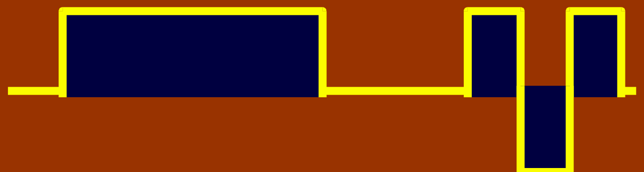
2)



3)



4)



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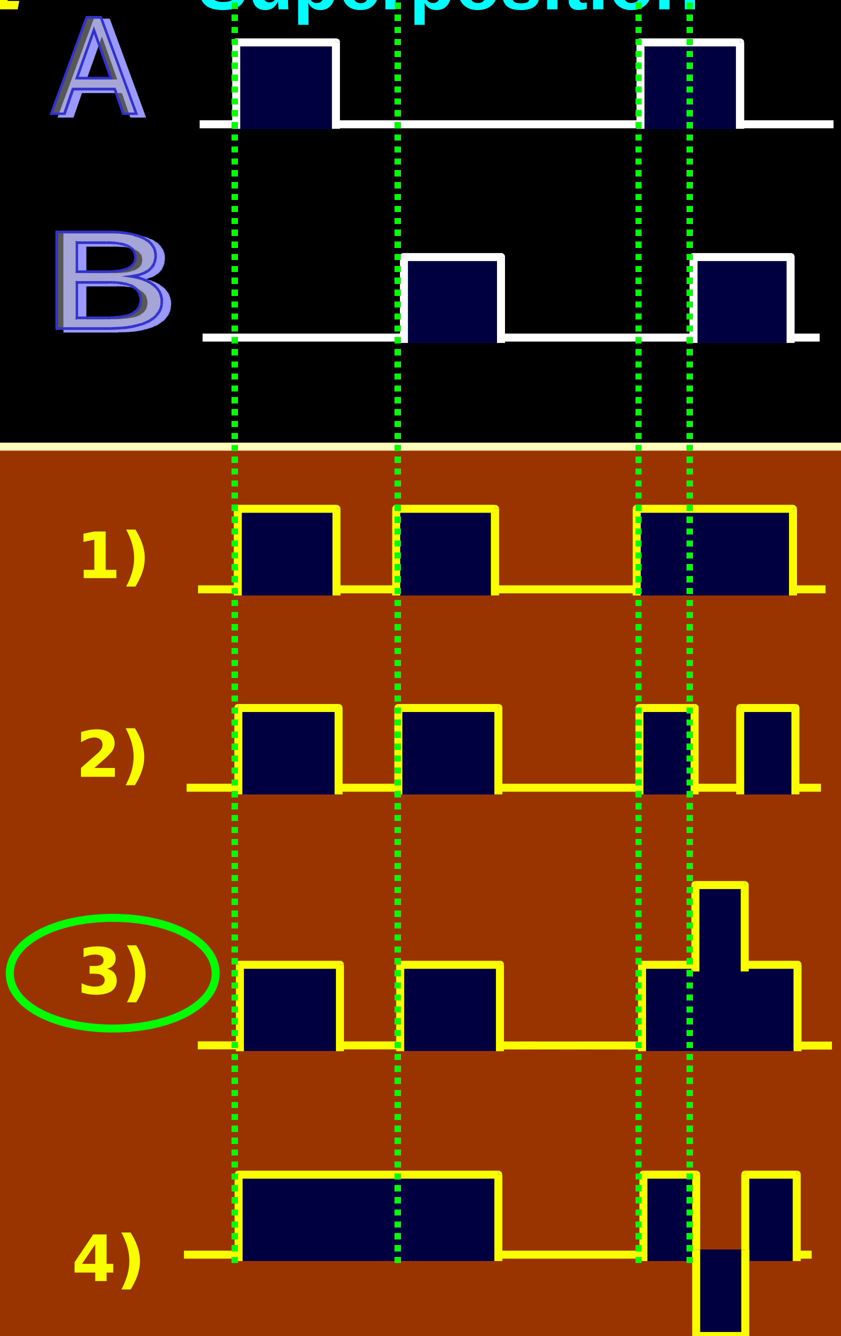
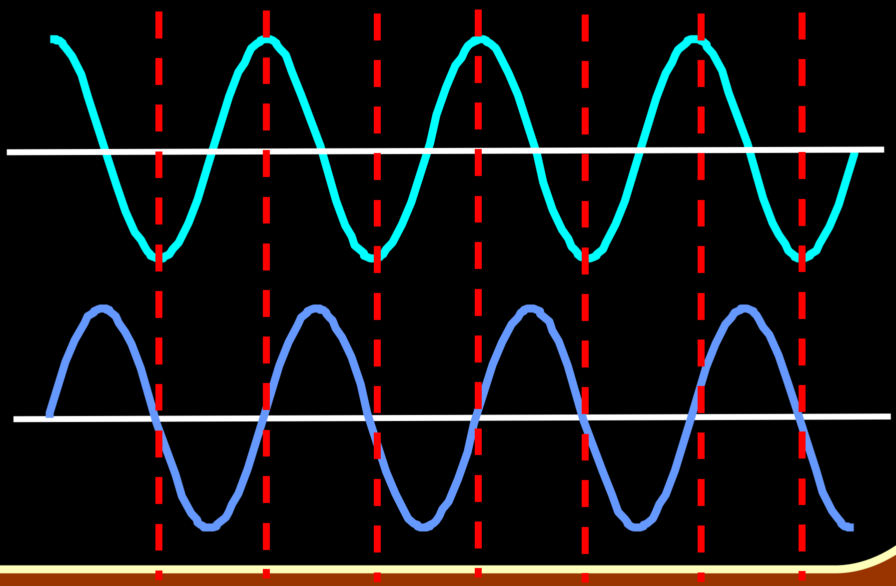



The amplitudes of waves A and B have to be added at each point!

# *ConcepTest 24.2a* Phase Difference I

**The two waves shown are**

1) out of phase by 180°
2) out of phase by 90°
3) out of phase by 45°
4) out of phase by 360°
5) in phase



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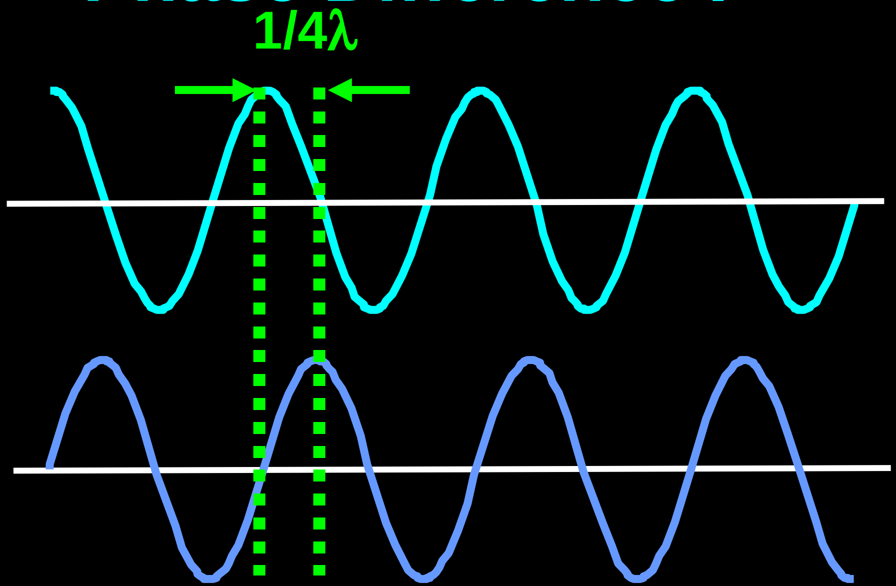



The two waves are out of phase by **1/4 wavelength** (as seen in the figure) , which corresponds to a phase difference of **90°**.

**Follow-up:** What would the waves look like for no. 4 to be correct?

## *ConcepTest 24.2b* Phase Difference II

Two light sources emit waves of $\lambda$ = 1 m which are in phase. The two waves from these sources meet at a distant point. Wave 1 traveled 2 m to reach the point, and wave 2 traveled 3 m. When the waves meet, they are

1) out of phase by 180°
2) out of phase, but not by 180°
3) in phase

# *ConcepTest 24.2b* Phase Difference II

Two light sources emit waves of $\lambda$ = 1 m which are in phase. The two waves from these sources meet at a distant point. Wave 1 traveled 2 m to reach the point, and wave 2 traveled 3 m. When the waves meet, they are

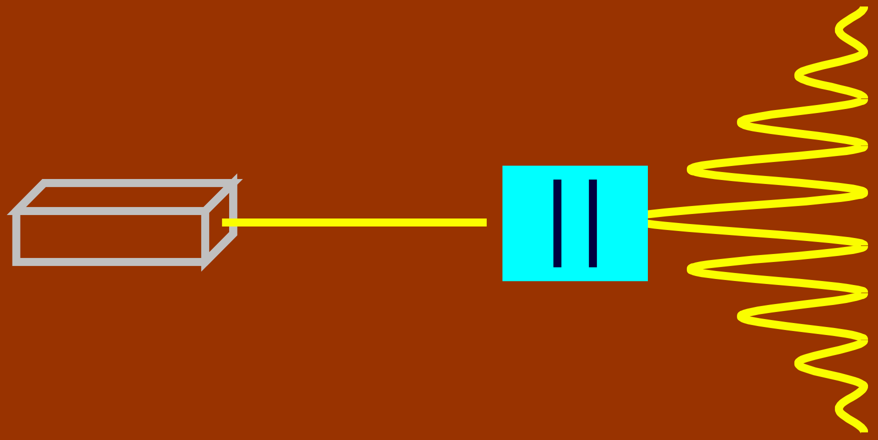
1) out of phase by 180°
2) out of phase, but not by 180°
3) in phase

Since $\lambda$ = 1 m, wave 1 has traveled twice this wavelength while wave 2 has traveled three times this wavelength. Thus, their phase difference is one full wavelength, which means they are still in phase.

# *ConcepTest 24.3a* Double Slits I

In a double-slit experiment, when the wavelength of the light is increased, the interference pattern

1) spreads out
2) stays the same
3) shrinks together
4) disappears



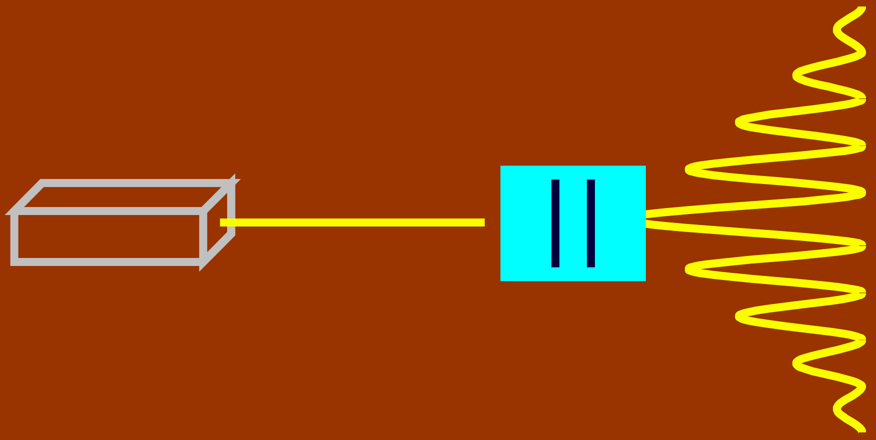
# ConcepTest 24.3a Double Slits I

In a double-slit experiment, when the wavelength of the light is increased, the interference pattern

1) spreads out
2) stays the same
3) shrinks together
4) disappears

$d \sin\theta = m\lambda$

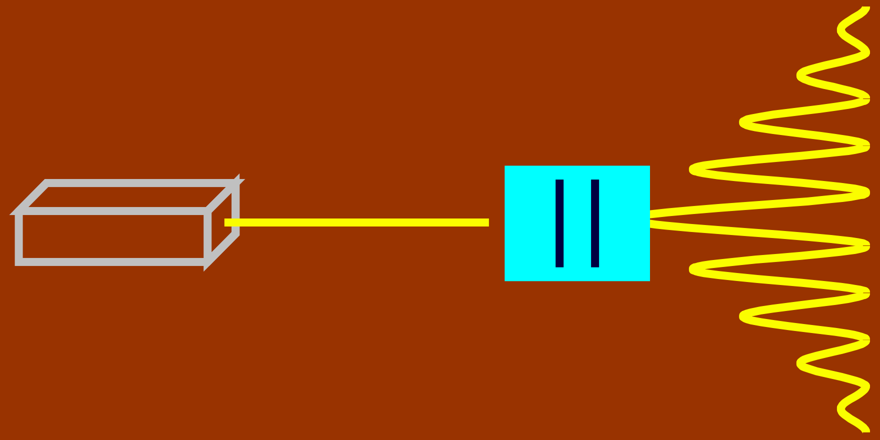
If $\lambda$ is increased and $d$ does not change, then $\theta$ must increase, so the pattern spreads out.



# *ConcepTest 24.3b* Double Slits II

If instead the **slits** are moved **farther apart** (without changing the wavelength) the interference pattern

1) spreads out
2) stays the same
3) shrinks together
4) disappears



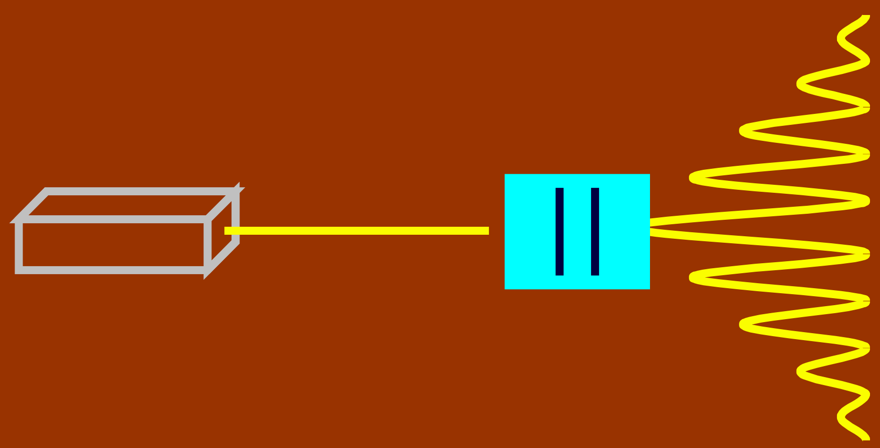
# ConcepTest 24.3b Double Slits II

If instead the slits are moved farther apart (without changing the wavelength) the interference pattern

1) spreads out
2) stays the same
3) shrinks together
4) disappears

$d \sin\theta = m\lambda$

If instead $d$ is increased and $\lambda$ does not change, then $\theta$ must decrease, so the pattern shrinks together

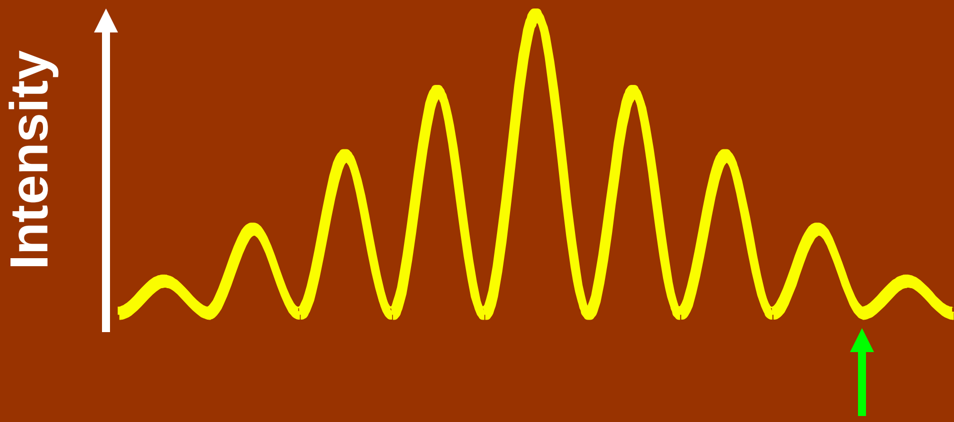


**Follow-up:** When would the interference pattern disappear?

# *ConcepTest 24.4* Path Difference

**In a double-slit experiment, what *path difference* have the waves from each slit traveled to give a minimum at the indicated position?**

1) there is no difference
2) half a wavelength
3) one wavelength
4) three wavelengths
5) more than three wavelengths



# *ConcepTest 24.4* Path Difference

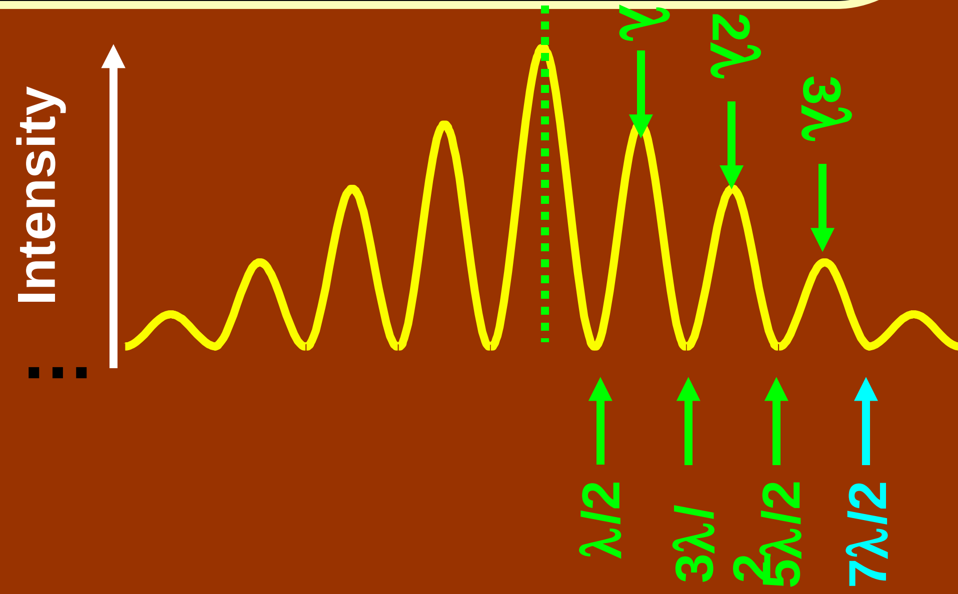
In a double-slit experiment, what *path difference* have the waves from each slit traveled to give a minimum at the indicated position?

1) there is no difference
2) half a wavelength
3) one wavelength
4) three wavelengths
5) more than three wavelengths

**For Destructive Interference**

$\delta = 1/2\ \lambda,\ 3/2\ \lambda,\ 5/2\ \lambda,\ 7/2\ \lambda,\ \ldots$

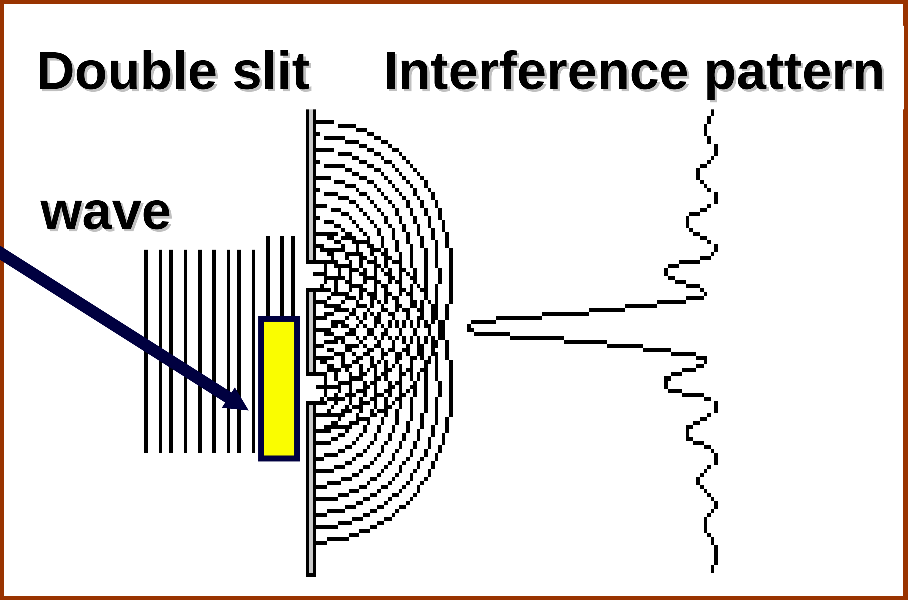
$= (m + 1/2)\ \lambda$



# *ConcepTest 24.5* Interference Pattern

An interference pattern is seen from two slits. Now cover one slit with **glass**, introducing a ***phase difference of 180°* (1/2 wavelength)** at the slits. How is the pattern altered?

1) pattern vanishes
2) pattern expands
3) bright and dark spots are interchanged
4) pattern shrinks
5) no change at all

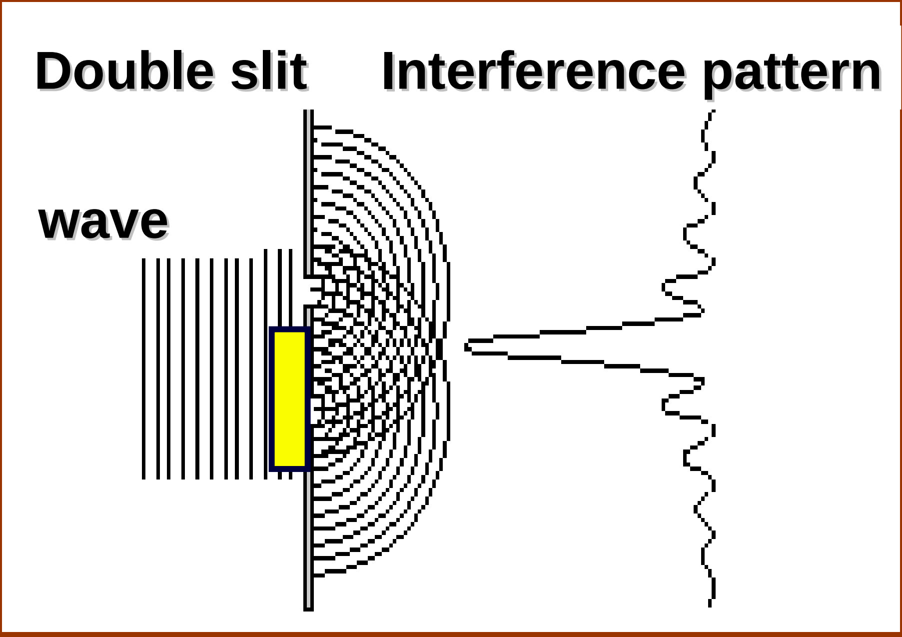


# ConcepTest 24.5 Interference Pattern

An interference pattern is seen from two slits. Now cover one slit with glass, introducing a *phase difference of 180°* *(1/2 wavelength)* at the slits. How is the pattern altered?

1) pattern vanishes
2) pattern expands
3) bright and dark spots are interchanged
4) pattern shrinks
5) no change at all

If the waves originating from the two slits have a phase difference of 180° when they start off, the central spot will now be dark !! To the left and the right, there will be bright spots. Thus, bright and dark spots are interchanged.

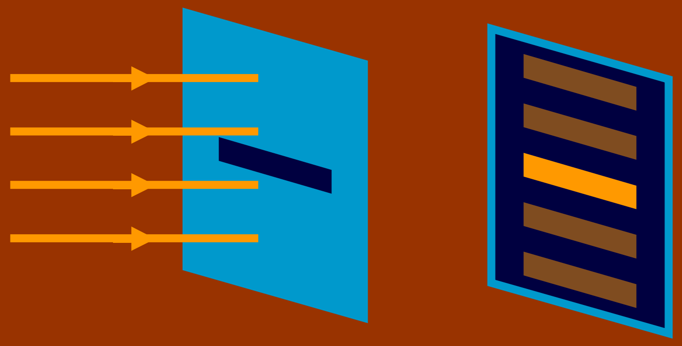



**Follow-up:** What happens when the phase difference is 90°?

# *ConcepTest 24.5a* Diffraction I

The diffraction pattern below arises from a single slit. If we would like to sharpen the pattern, i.e., make the central bright spot narrower, what should we do to the slit width?

1) narrow the slit
2) widen the slit
3) enlarge the screen
4) close off the slit



# *ConcepTest 24.5a* Diffraction I

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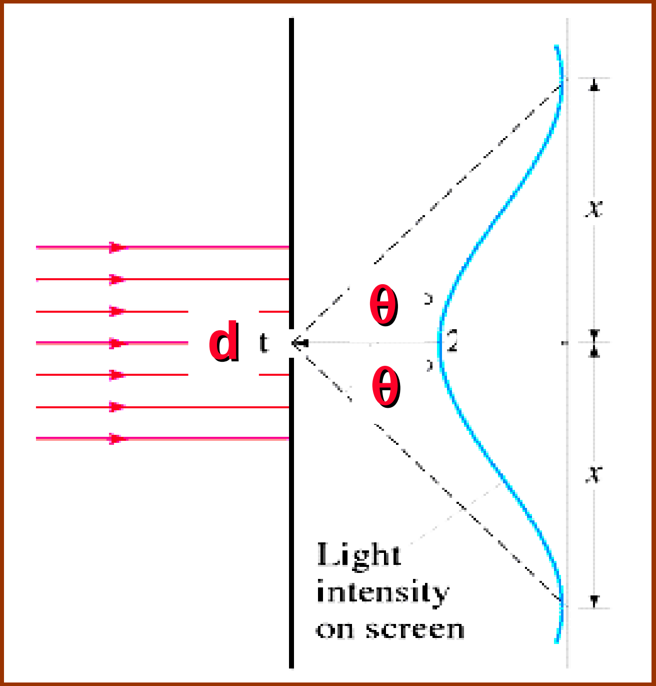
1) narrow the slit
2) widen the slit
3) enlarge the screen
4) close off the slit

The angle at which one finds the first minimum is:

$$\sin\theta = \lambda / d$$

The central bright spot can be narrowed by having a smaller angle. This in turn is accomplished by widening the slit.



# ConcepTest 24.5b Diffraction II

*Blue light* of wavelength $\lambda$ passes through a single slit of width $d$ and forms a diffraction pattern on a screen. If the *blue light* is replaced by *red light* of wavelength $2\lambda$, the original diffraction pattern can be reproduced if the slit width is changed to:

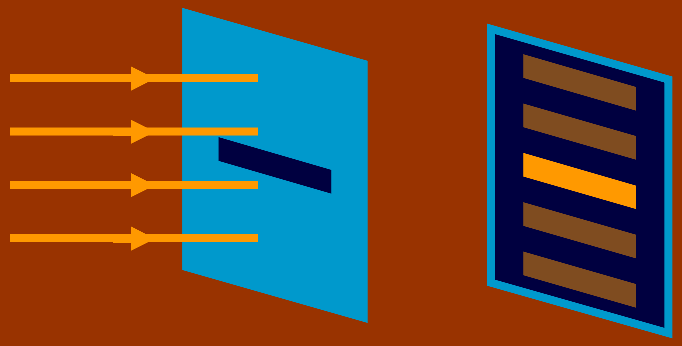
1) $d/4$

2) $d/2$

3) no change needed

4) $2d$

5) $4d$



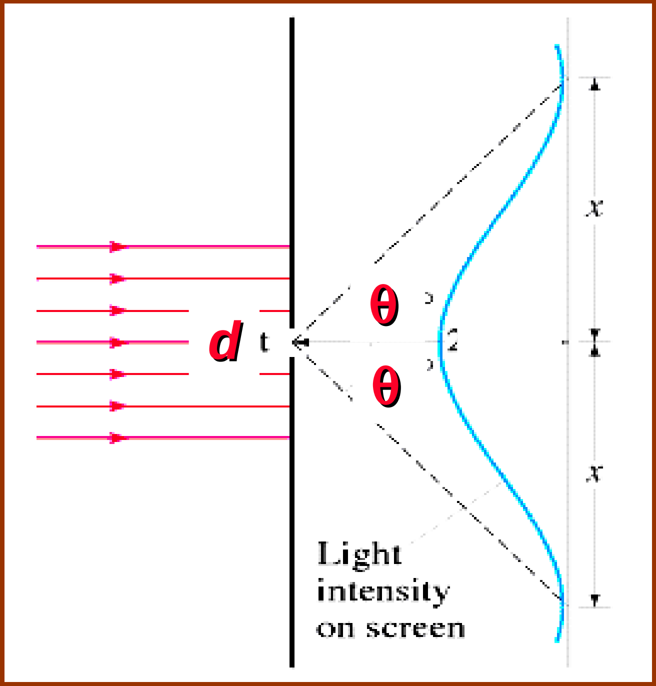
# ConcepTest 24.5b Diffraction II

**Blue light** of wavelength λ passes through a single slit of **width *d*** and forms a diffraction pattern on a screen. If the *blue light* is replaced by *red light* of wavelength *2λ*, the original diffraction pattern can be reproduced if the slit width is changed to:

1) *d*/4
2) *d*/2
3) no change needed
4) 2 *d*
5) 4 *d*

**$d \sin\theta = m\lambda$ (minima)**

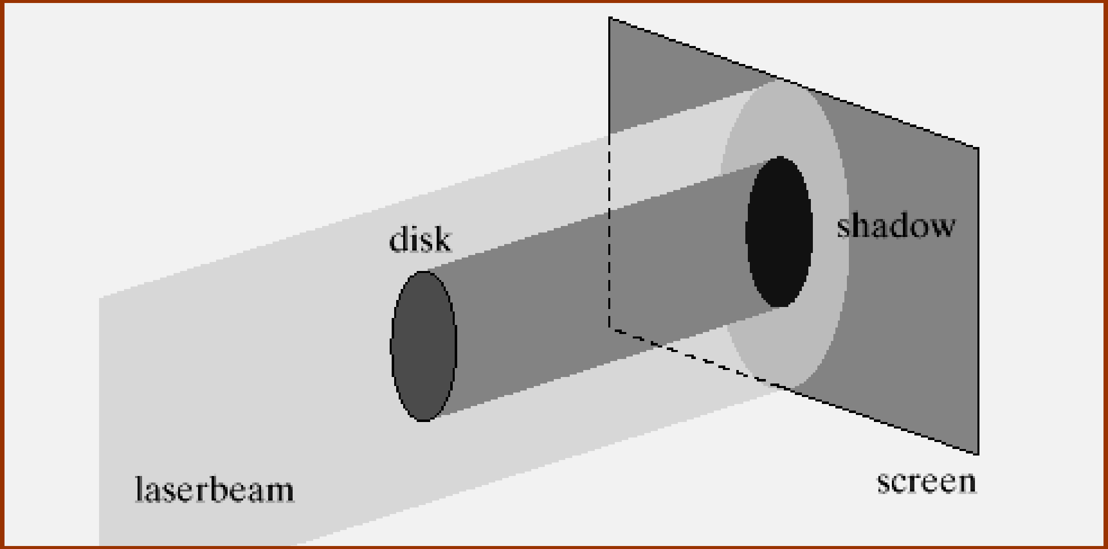
If $\lambda \rightarrow 2\lambda$ then we must have $d \rightarrow 2d$ for $\sin\theta$ to remain unchanged (and thus give the same diffraction pattern).



# ConcepTest 24.6 Diffraction Disk

Imagine holding a circular disk in a beam of monochromatic light. If diffraction occurs at the edge of the disk, the center of the shadow is

1) darker than the rest of the shadow
2) a bright spot
3) bright or dark, depends on the wavelength
4) bright or dark, depends on the distance to the screen



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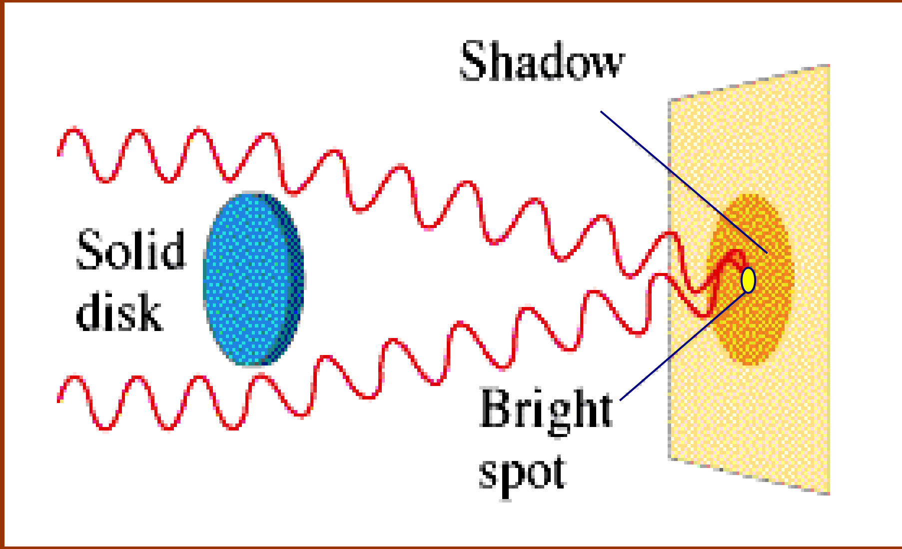
1) darker than the rest of the shadow
2) a bright spot
3) bright or dark, depends on the wavelength
4) bright or dark, depends on the distance to the screen

By symmetry, all of the waves coming from the edge of the disk ***interfere constructively*** in the middle because they are all **in phase** and they all travel the **same distance** to the screen.

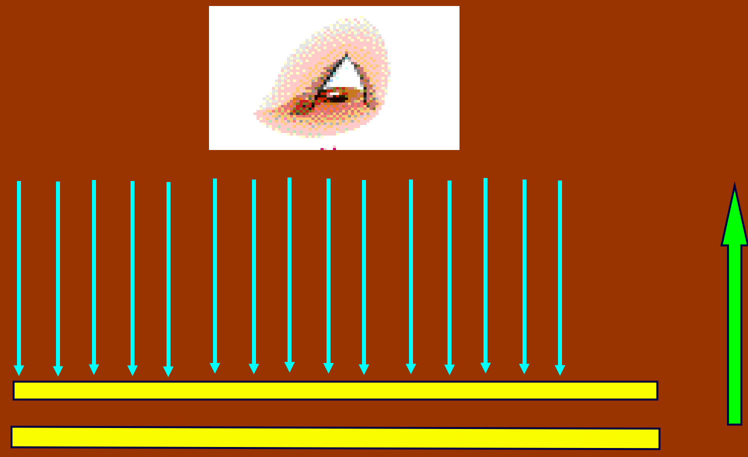



**Follow-up:** What if the disk is oval and not circular?

# *ConcepTest 24.7a* Parallel Slides I

Consider two identical microscope slides in air illuminated with light from a laser. The slides are exactly parallel, and the top slide is moving slowly upward. What do you see when looking from the top view?

1) All black
2) All white
3) Fringes moving apart
4) Alternately all black, then all bright



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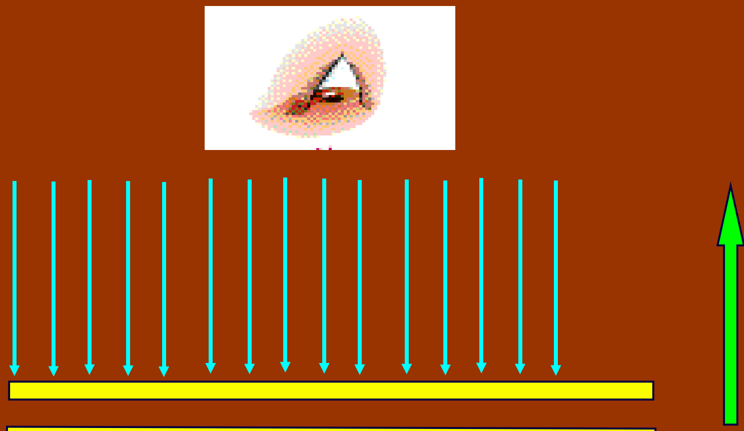
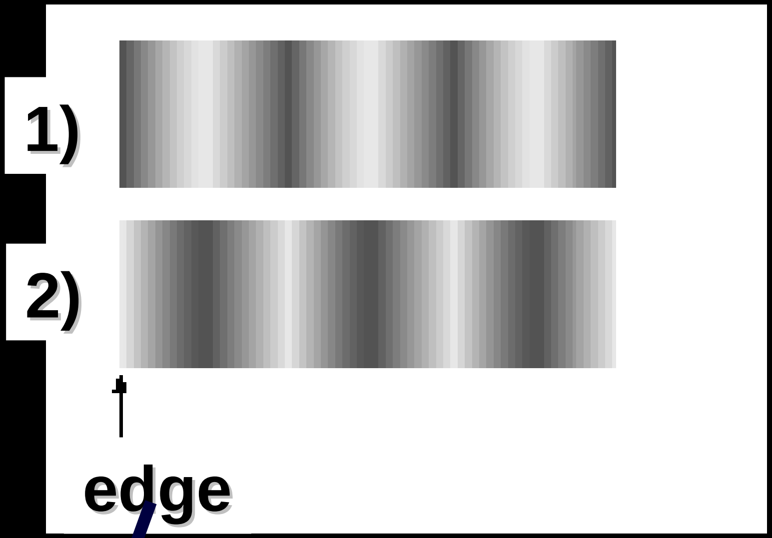
1) All black
2) All white
3) Fringes moving apart
4) Alternately all black, then all bright

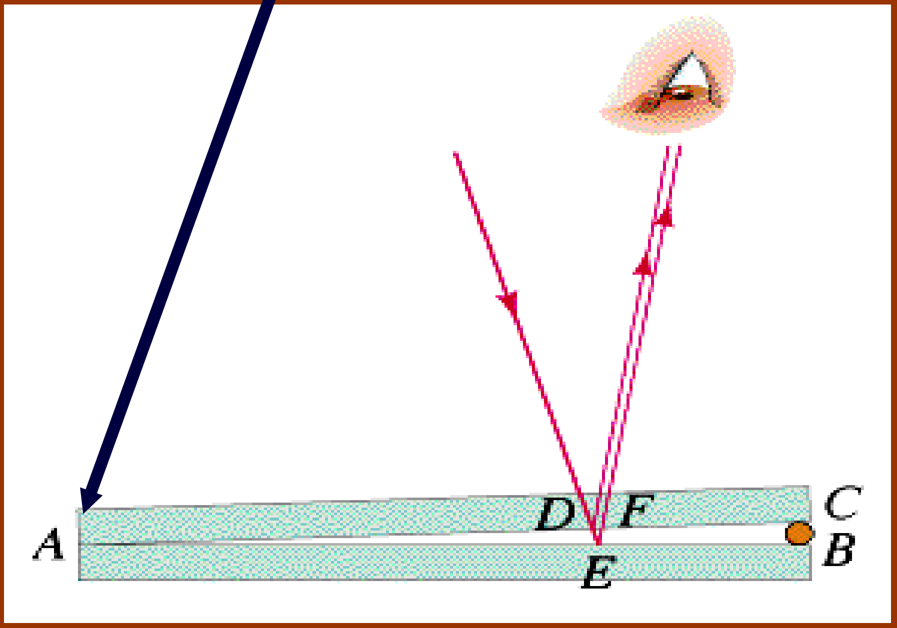
**As the distance between the two slides decreases, the path difference between the interfering rays changes. Thus, the phase between the interfering rays keeps changing, alternately *in phase (constructive)* and *out of phase (destructive)* as the top slide moves.**



# ConcepTest 24.7b Parallel Slides II

A laser shines on a pair of identical glass microscope slides that form a very narrow edge. The waves reflected from the top and the bottom slide interfere. What is the interference pattern from top view?



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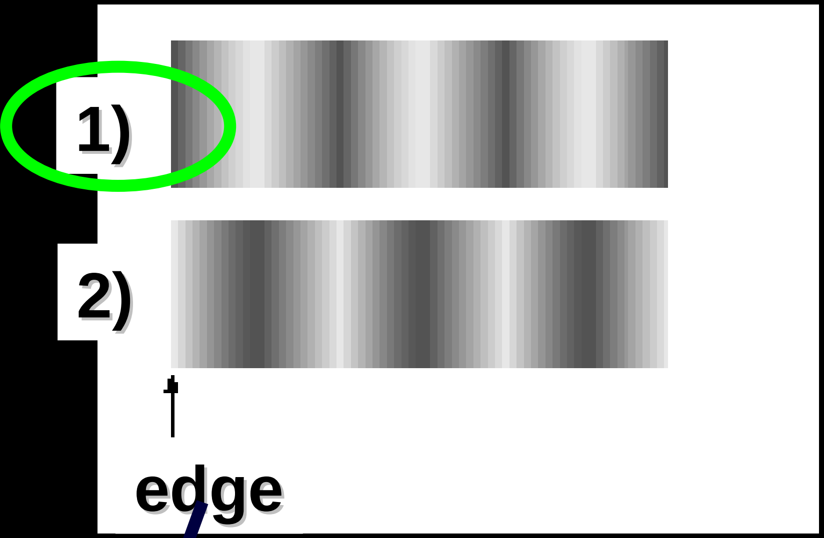
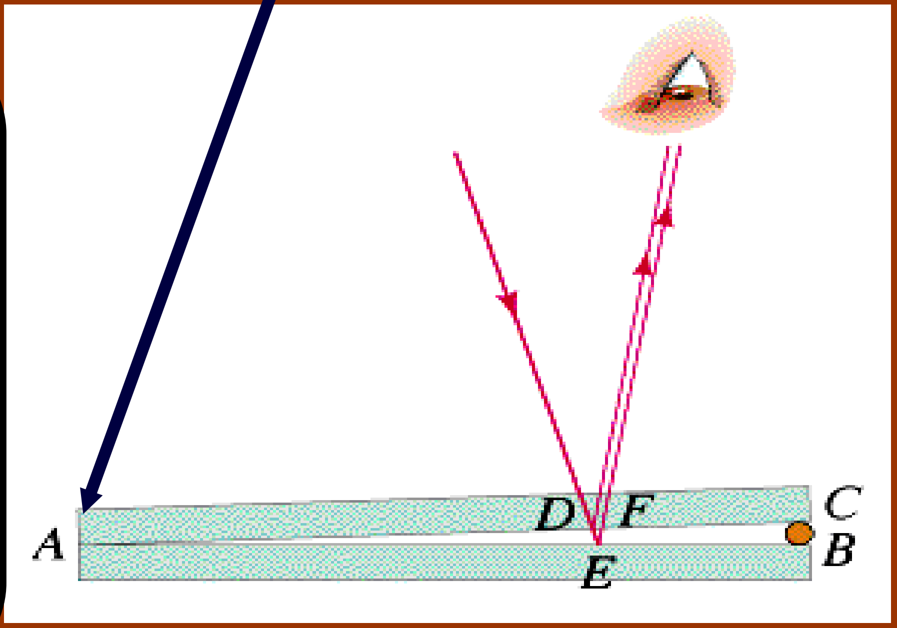



Right at the edge, the two reflected rays have ***no path length difference*** and therefore should interfere ***constructively***. However, the light ray reflected at the lower surface (point E) ***changes phase by λ/2*** because the index of refraction of glass is larger than that of air.



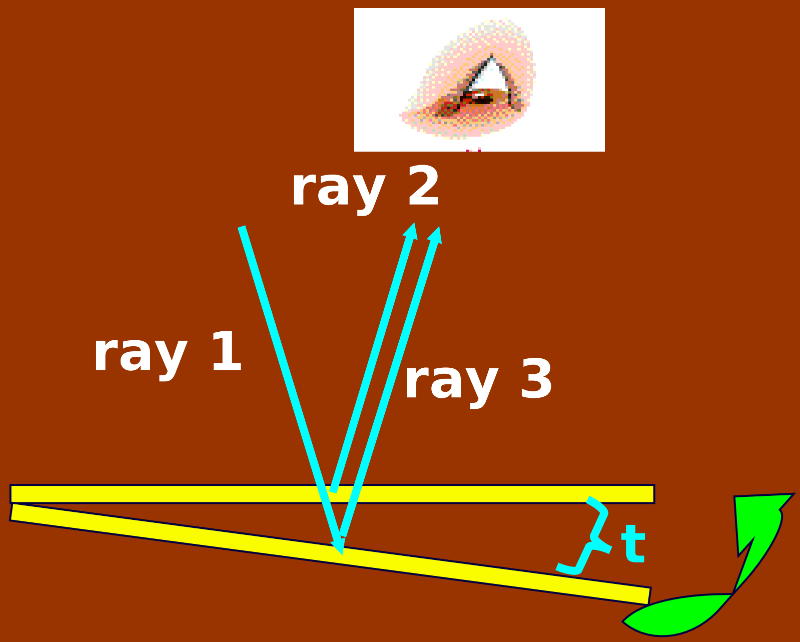
# *ConcepTest 24.7c* Parallel Slides III

Consider two identical microscopic slides in air illuminated with light from a laser. The bottom slide is rotated upwards so that the wedge angle gets a bit smaller. What happens to the interference fringes?

1) Spaced farther apart

2) Spaced closer together

3) No change



# *ConcepTest 24.7c* Parallel Slides III

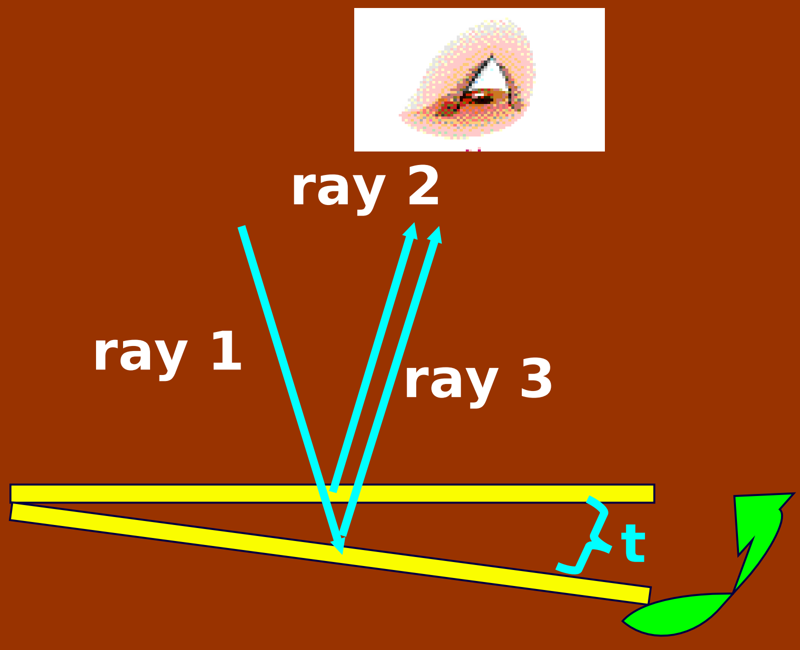
Consider two identical microscopic slides in air illuminated with light from a laser. The bottom slide is rotated upwards so that the wedge angle gets a bit smaller. What happens to the interference fringes?

1) Spaced farther apart
2) Spaced closer together
3) No change

The path difference between ray #2 and ray #3 is *2t* (in addition, ray #3 experiences a phase change of 180°). Thus, the dark fringes will occur for:

$$2t = m\lambda \qquad m = 0,1,2,\ldots$$

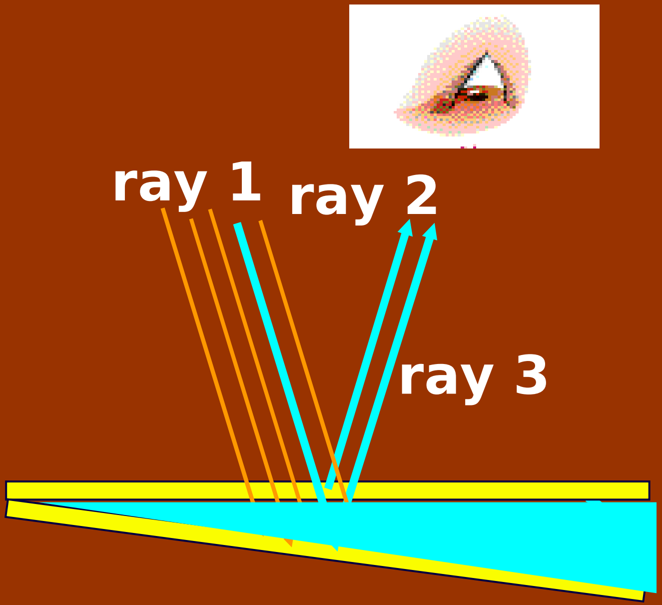
If *t* gets smaller, ray #2 and ray #3 have to be farther apart before they can interfere, so the fringes move apart.



# *ConcepTest 24.7d* Parallel Slides IV

Two identical microscopic slides in air illuminated with light from a laser are creating an interference pattern. The space between the slides is now filled with water (*n*=1.33). What happens to the interference fringes?

1) Spaced farther apart
2) Spaced closer together
3) No change



# ConcepTest 24.7d Parallel Slides IV

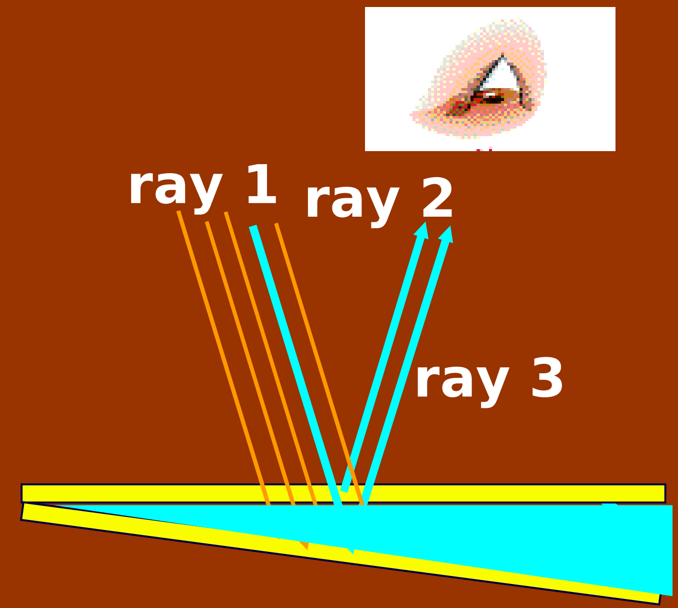
Two identical microscopic slides in air illuminated with light from a laser are creating an interference pattern. The space between the slides is now filled with water ($n$=1.33). What happens to the interference fringes?

1) Spaced farther apart
2) Spaced closer together
3) No change

The path difference between ray #2 and ray #3 is $2t$ (in addition, ray #3 experiences a phase change of 180°). Thus, the dark fringes will occur for:

$2t = m\lambda_{water}$ where $\lambda_{water} = \lambda_{air}/n$

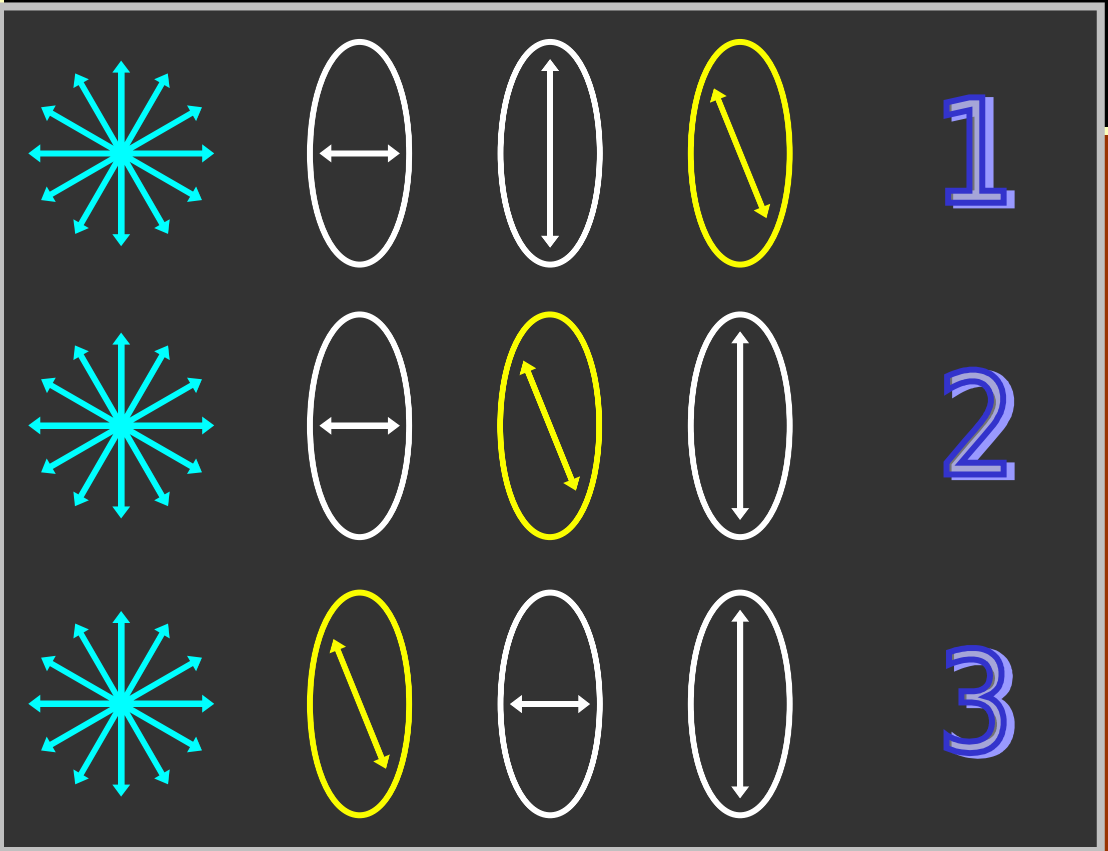
Thus, the water has decreased the wavelength of the light.



# *ConcepTest 24.8* Polarization

If unpolarized light is incident from the left, in which case will some light get through?

1) only case 1
2) only case 2
3) only case 3
4) cases 1 and 3
5) all three cases



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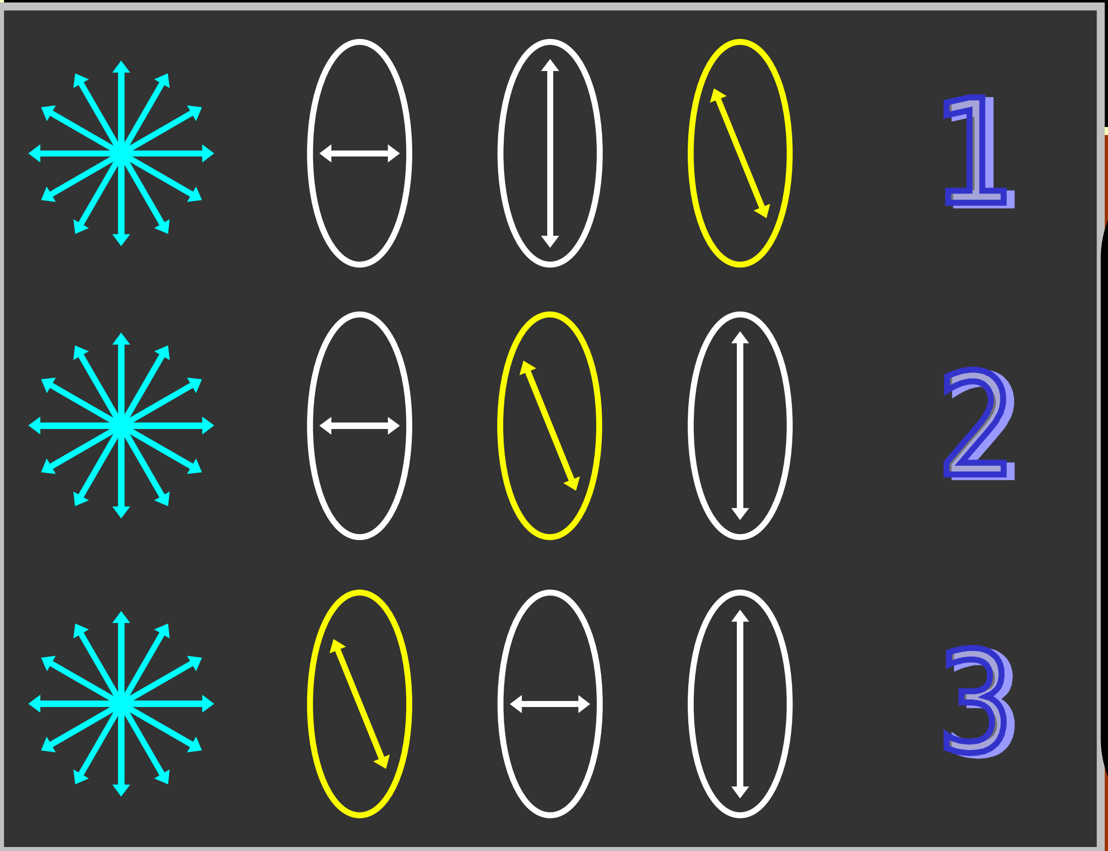


In cases 1 and 3, light is blocked by the adjacent horizontal and vertical polarizers. However, in case 2, the **intermediate 45° polarizer allows some light to get through** the last vertical polarizer.