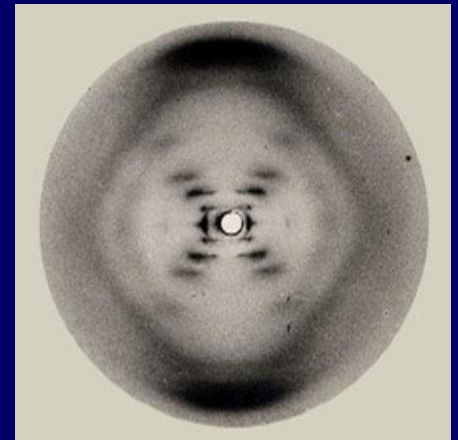


Physics 102: Lecture 20

Interference



Hour Exam 2 Results

- Even after scaling average is low (68%)
- Opportunity to Learn and Improve Score
 - Show work (clear/legible easy to grade)
 - No partial credit each question 100% or 0%
 - You must do every problem
 - Scaled score is average of raw + re-grade
- Turn in at lecture Wednesday April 16th

Phys 102 recent lectures

Light as a wave

- Lecture 14 – EM waves
- Lecture 15 – Polarization
- Lecture 20 & 21 – Interference & diffraction

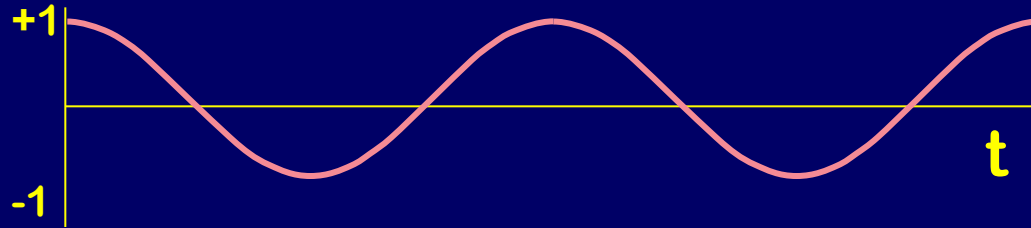
Light as a ray

- Lecture 16 – Reflection
- Lecture 17 – Spherical mirrors & refraction
- Lecture 18 – Refraction & lenses
- Lecture 19 – Lenses & your eye

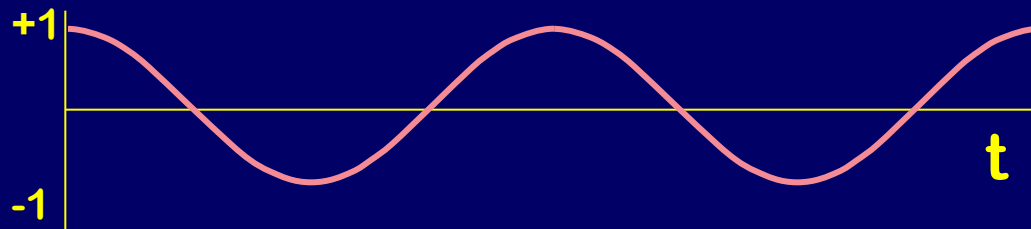


Superposition

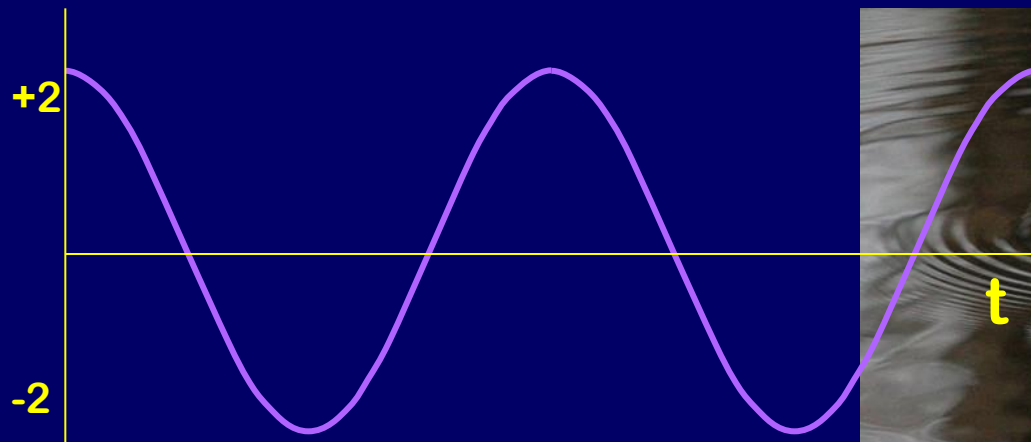
Constructive Interference



+



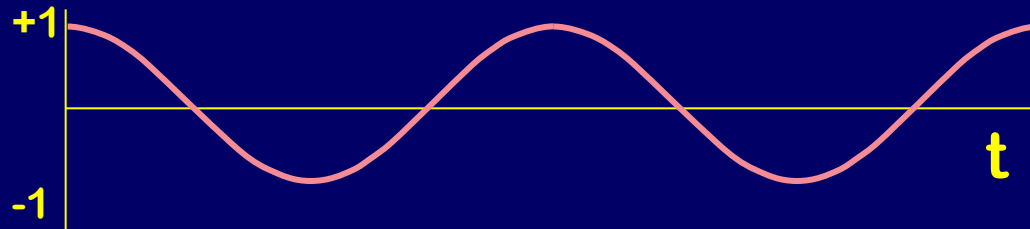
In Phase



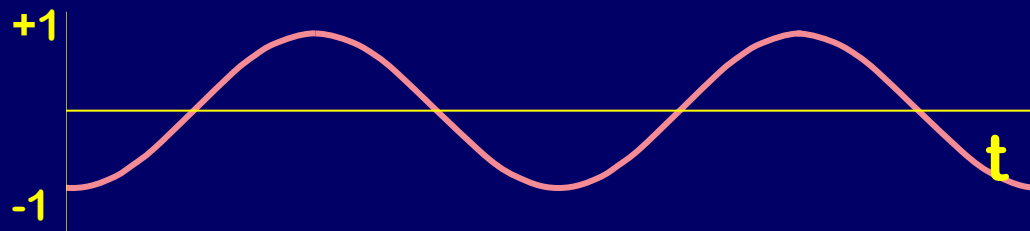


Superposition

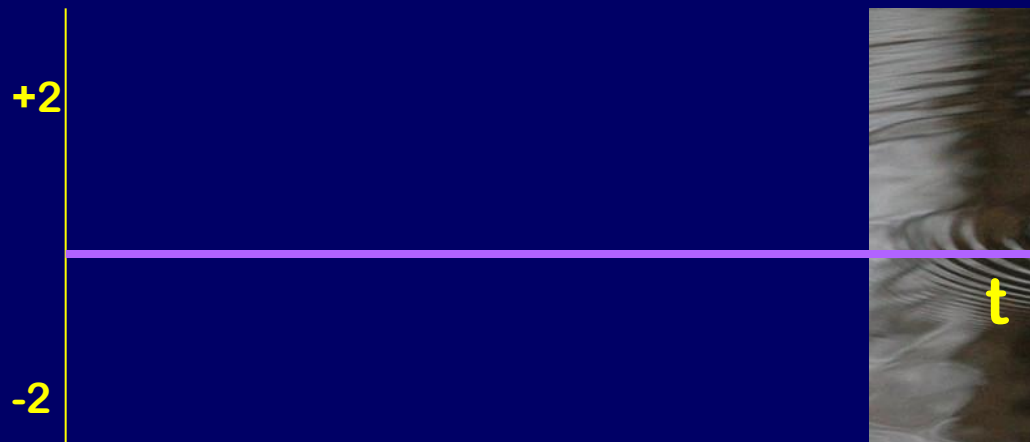
Destructive Interference



+

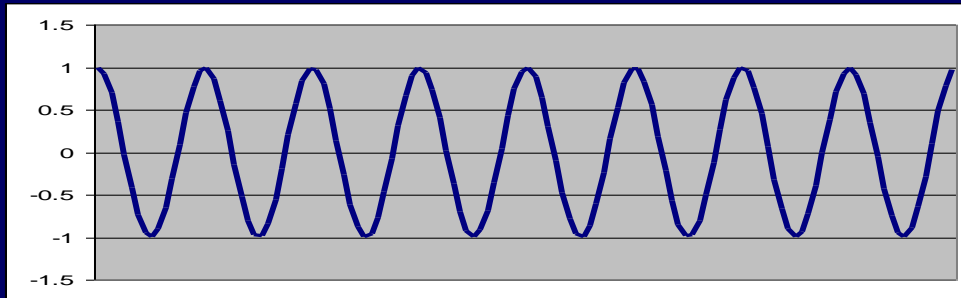


Out of Phase
180 degrees

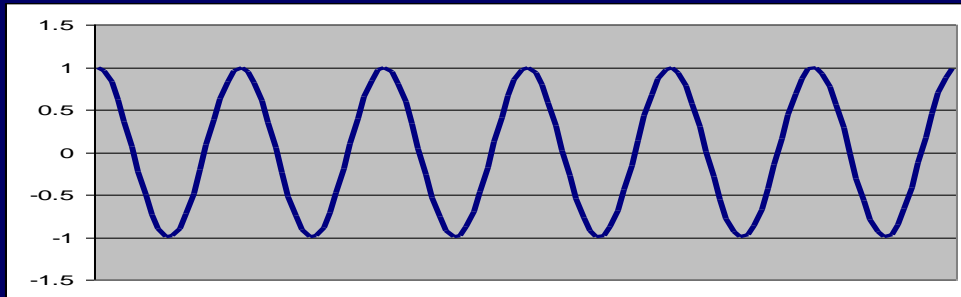




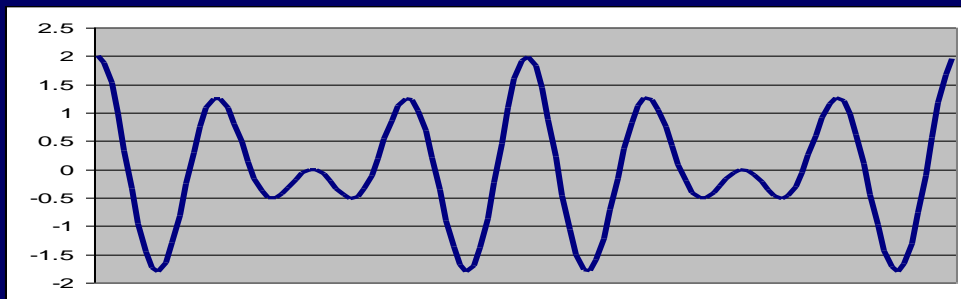
ACT: Superposition



+



Different f

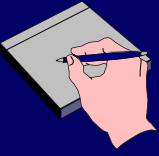


1) Constructive

2) Destructive

3) Neither

Constructive/Destructive Interference Requirements



- Need two (or more) waves
- Must have same frequency
- Must be coherent (i.e. waves must have definite phase relation)

Destructive interference:

- Waves are out of phase by 180°
- Path difference d between waves = $\lambda/2, 3\lambda/2, 5\lambda/2, \dots$
- $d/\lambda = \delta = 1/2, 3/2, 5/2, \dots$



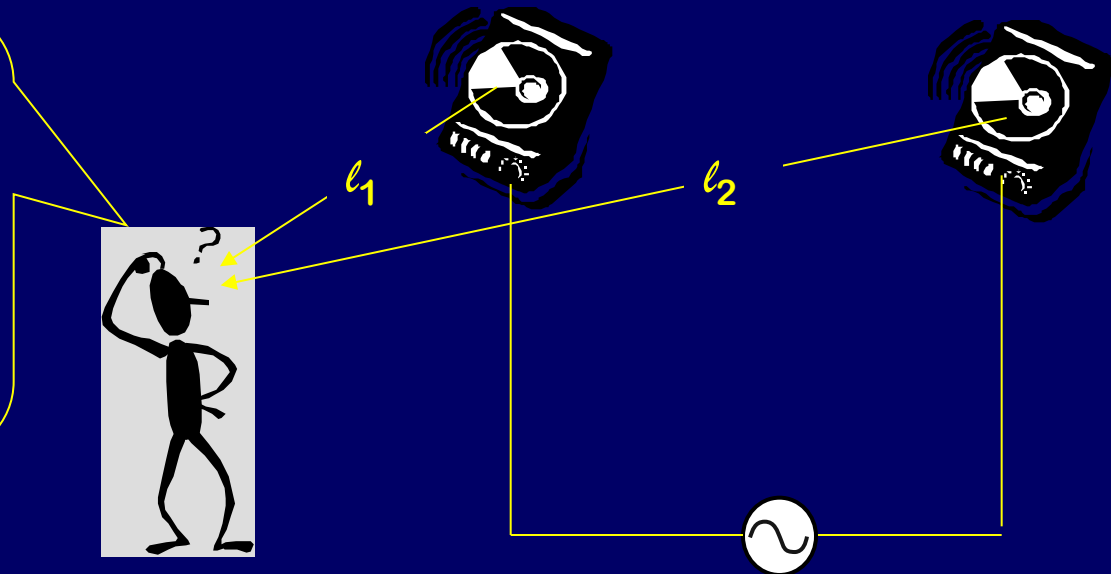
Constructive interference

- Waves are in phase
- Path difference d between waves = $0, \lambda, 2\lambda, 3\lambda, \dots$
- $d/\lambda = \delta = 0, 1, 2, \dots$

Demo: Interference for Sound ...

For example, a pair of speakers, driven in phase, producing a tone of a single f and λ :

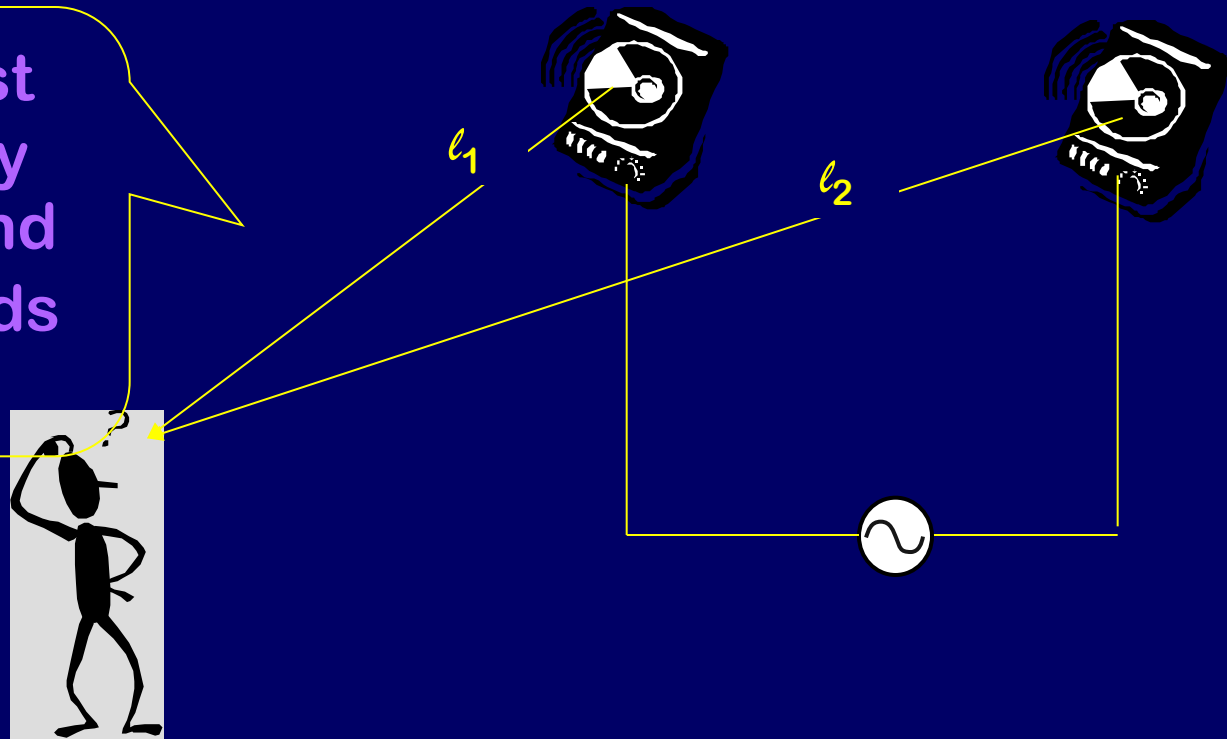
hmmm... I'm just far enough away that $\ell_2 - \ell_1 = \lambda/2$, and I hear no sound at all!

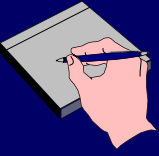


Demo: Interference for Sound ...

For example, a pair of speakers, driven in phase, producing a tone of a single f and λ :

hmmm... I'm just far enough away that $\ell_2 - \ell_1 = 10\lambda$, and the music sounds louder!





Interference for Light ...

- Either use single-frequency lasers, or...
- Or microwave / radio-frequency sources, or...
- Need two waves from single source taking two different paths

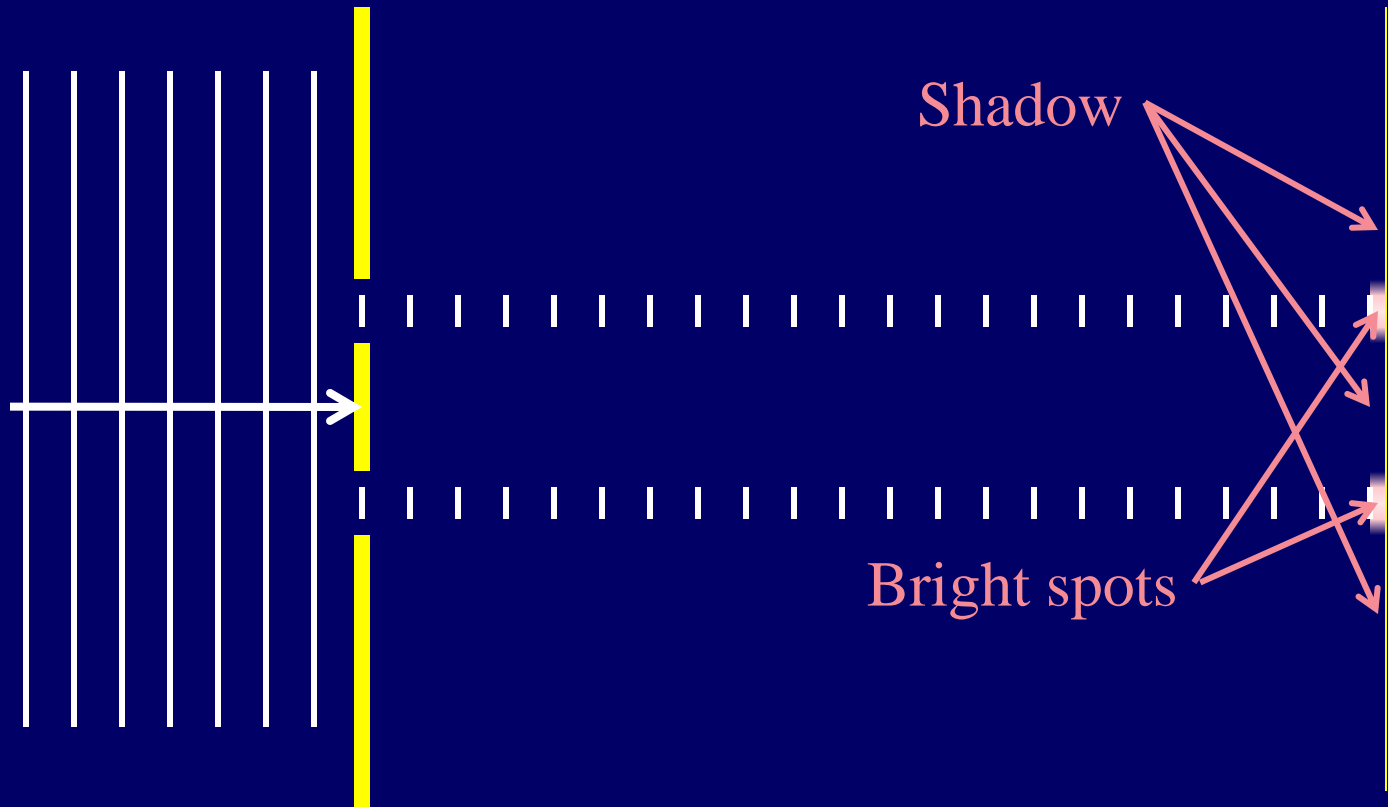
- Two slits
- Reflection (thin films)
- Diffraction

Today's lecture

Next lecture

Young's double slit/rays

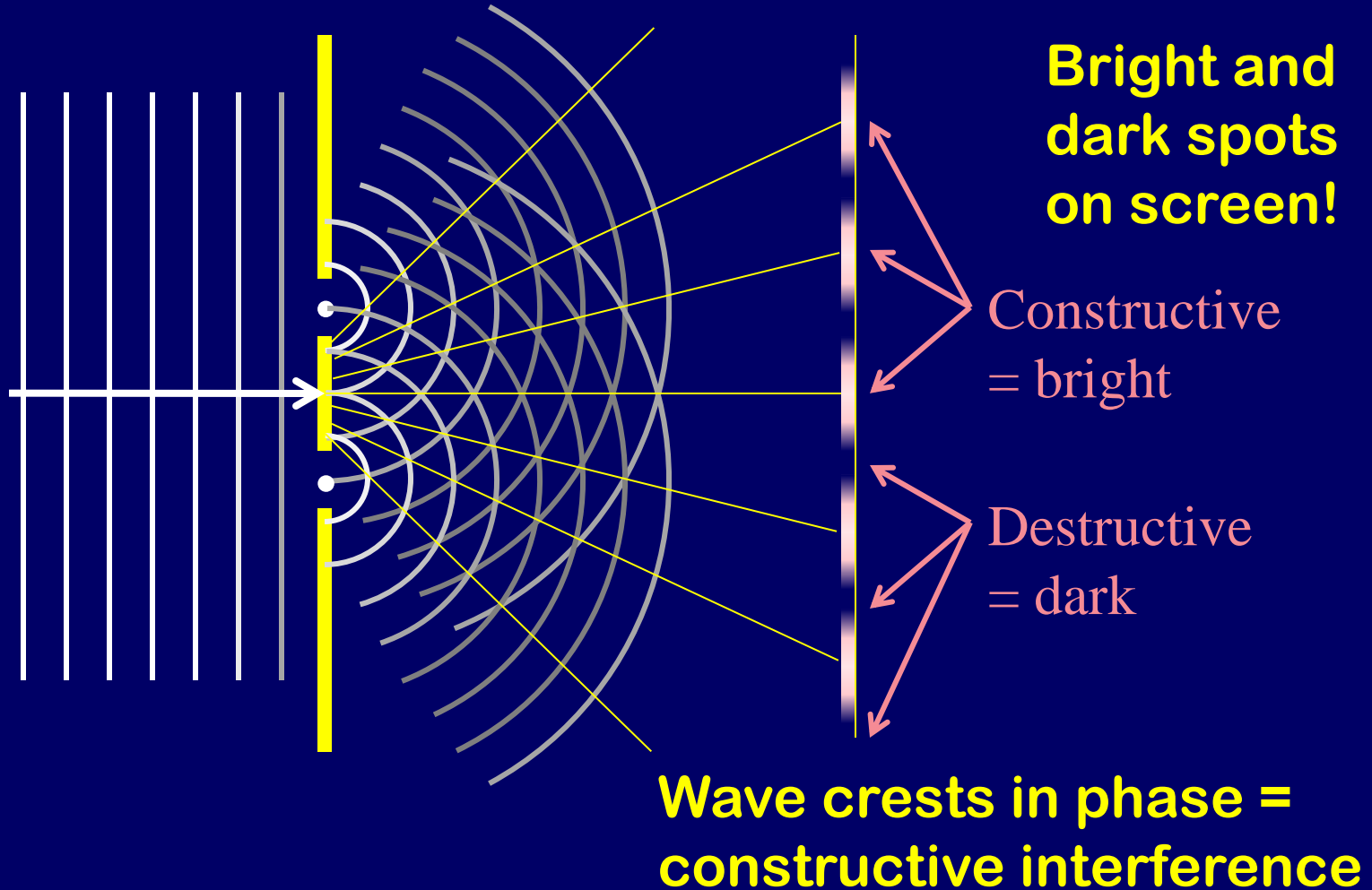
Monochromatic light travels through 2 slits onto a screen
What pattern emerges on the screen?



This is not what is actually seen!

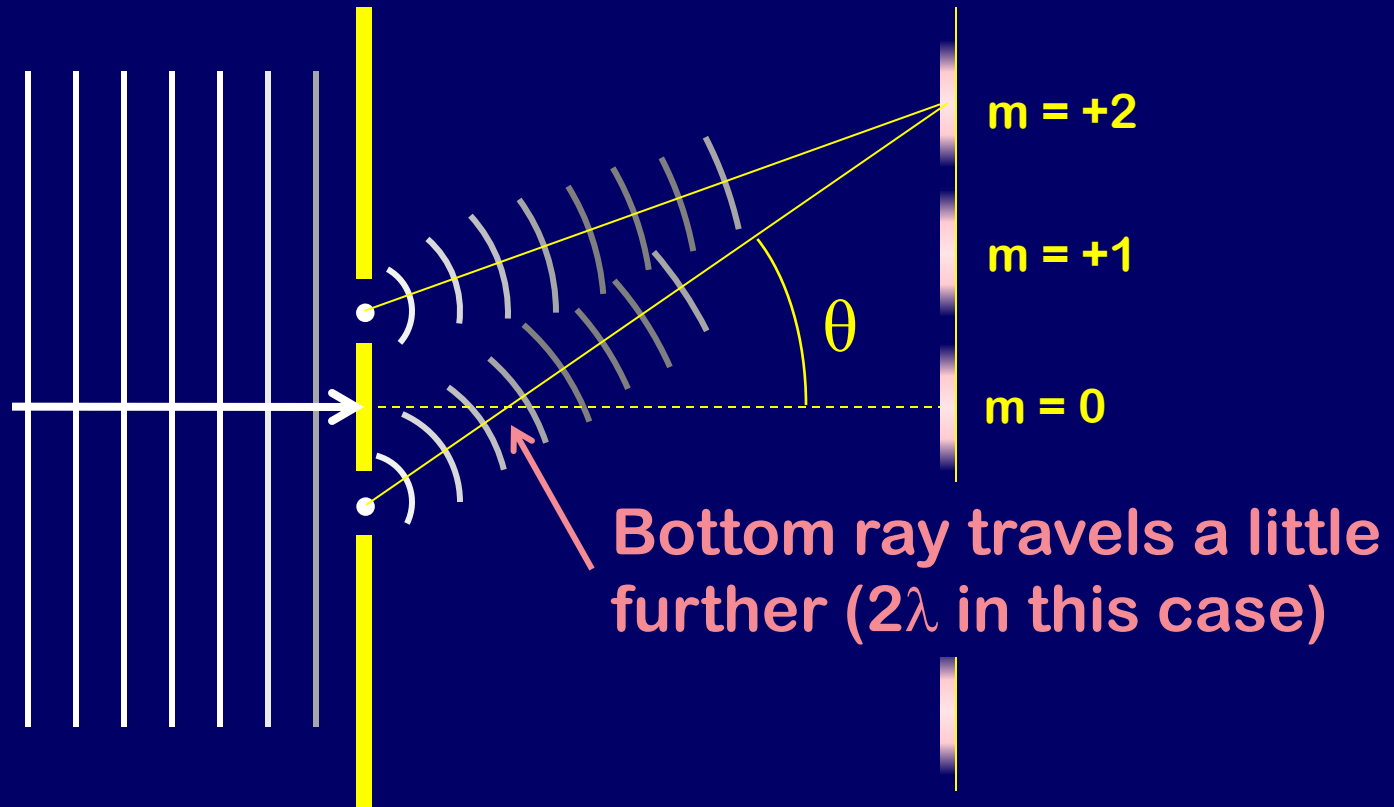
Young's double slit/Huygens

Recall Huygens' principle: Every point on a wave front acts as a source of tiny wavelets that move forward.



Young's double slit: Key idea

Consider two rays traveling at an angle θ :

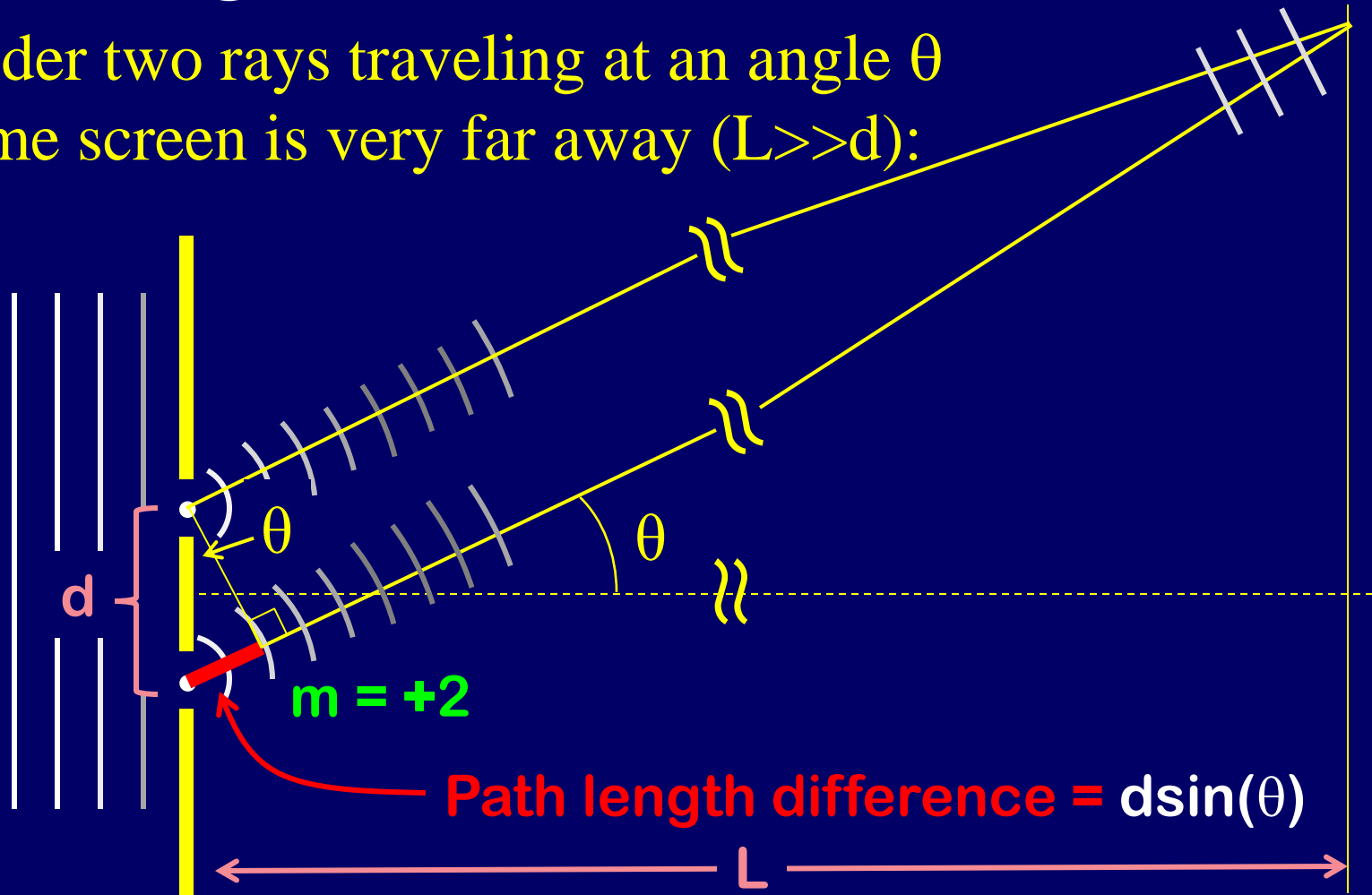


Key for interference is this small extra distance.

Young's double slit: Quantitative

Consider two rays traveling at an angle θ

Assume screen is very far away ($L \gg d$):



Constructive: $d \sin(\theta) = m\lambda$

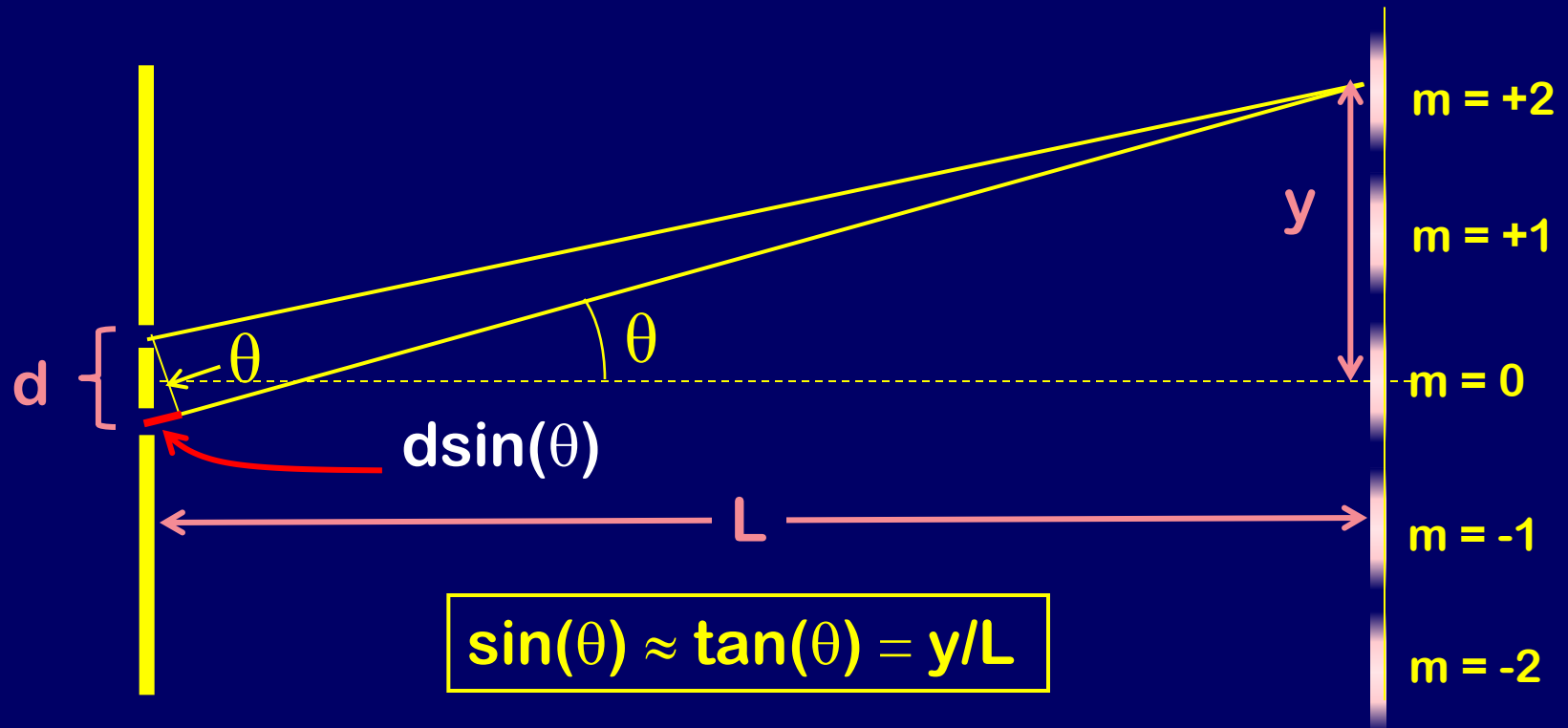
where $m = 0, \pm 1, \pm 2$

Destructive: $d \sin(\theta) = (m + 1/2)\lambda$

Need $\lambda < d$

Young's double slit: Quantitative

Assume screen is very far away ($L \gg d$), angles θ are small:



Constructive: $d \sin(\theta) = m\lambda$

$$y \approx m\lambda L/d$$

Destructive: $d \sin(\theta) = (m+1/2)\lambda$

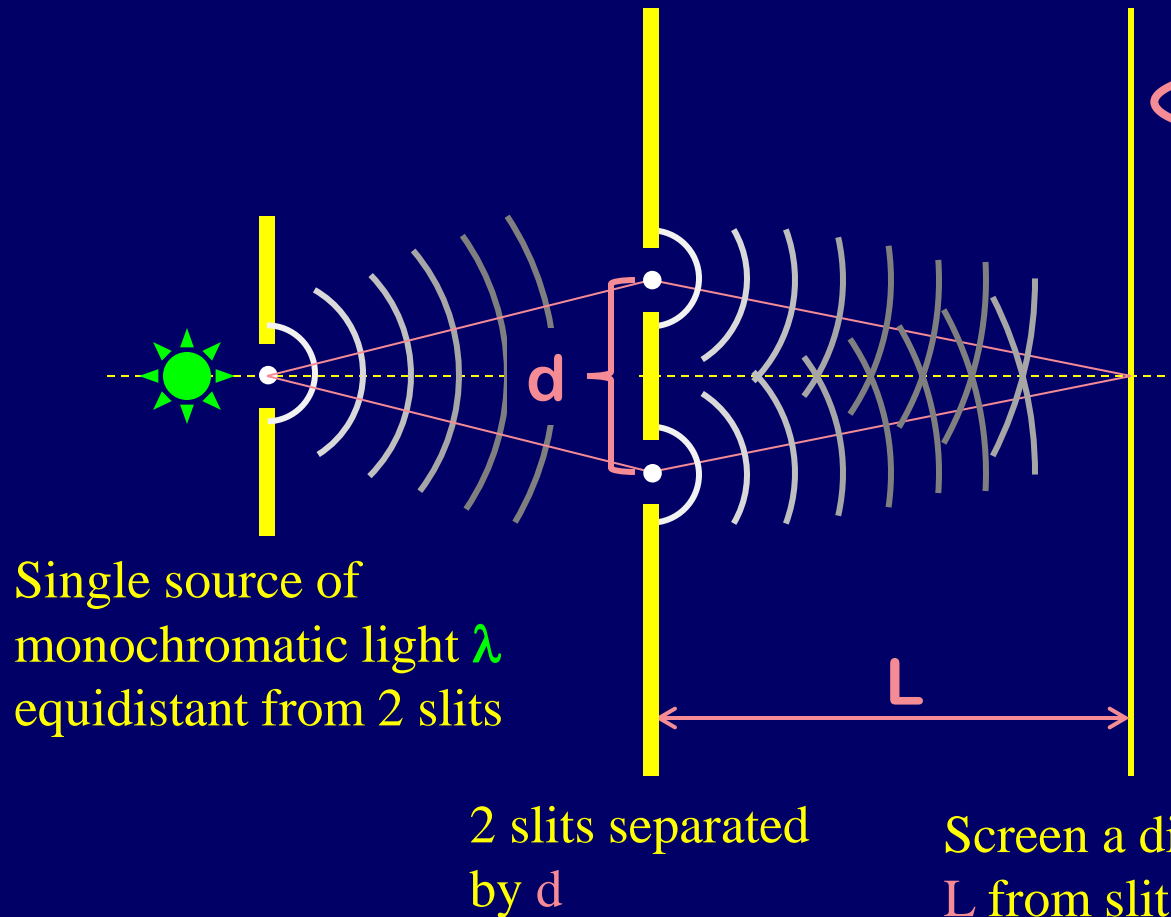
$$y \approx (m+1/2)\lambda L/d$$

$$m = 0, \pm 1, \pm 2$$



ACT: Young's Double Slit

Light waves from a single source travel through 2 slits before meeting on a screen. The interference right behind the slits will be:



A. Constructive

B. Destructive

C. Depends on L

The waves start in phase, and travel the same distance, so they will arrive in phase.



ACT/Checkpoint 1.1

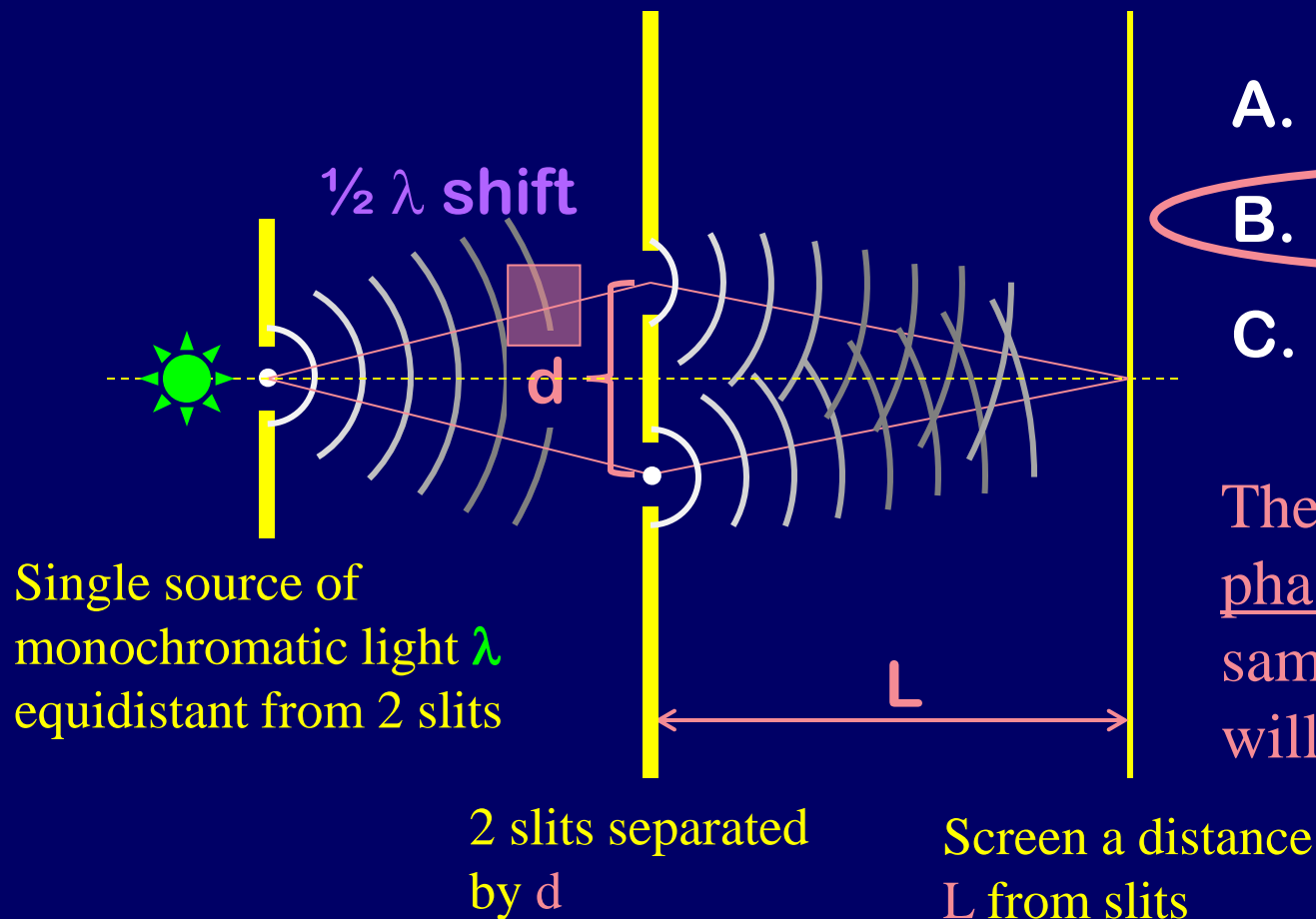
The experiment is modified so that one of the waves has its phase shifted by $\frac{1}{2} \lambda$. Now, the interference behind the slits will be:

A. Constructive

B. Destructive

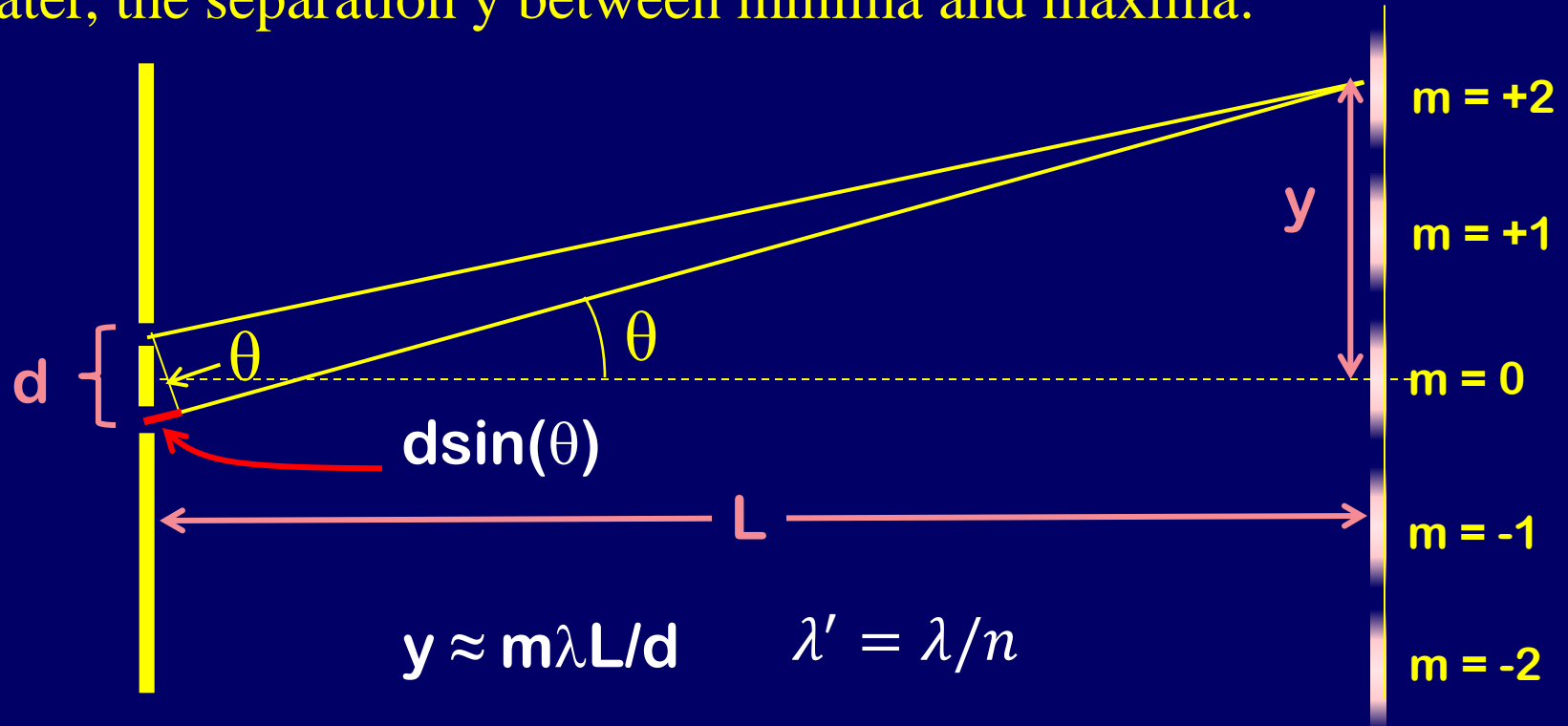
C. Depends on L

The waves start out of phase, and travel the same distance, so they will arrive out of phase.



ACT: Checkpoint 2

When this Young's double slit experiment is placed under water, the separation y between minima and maxima:



A) increases
16%

B) same
21%

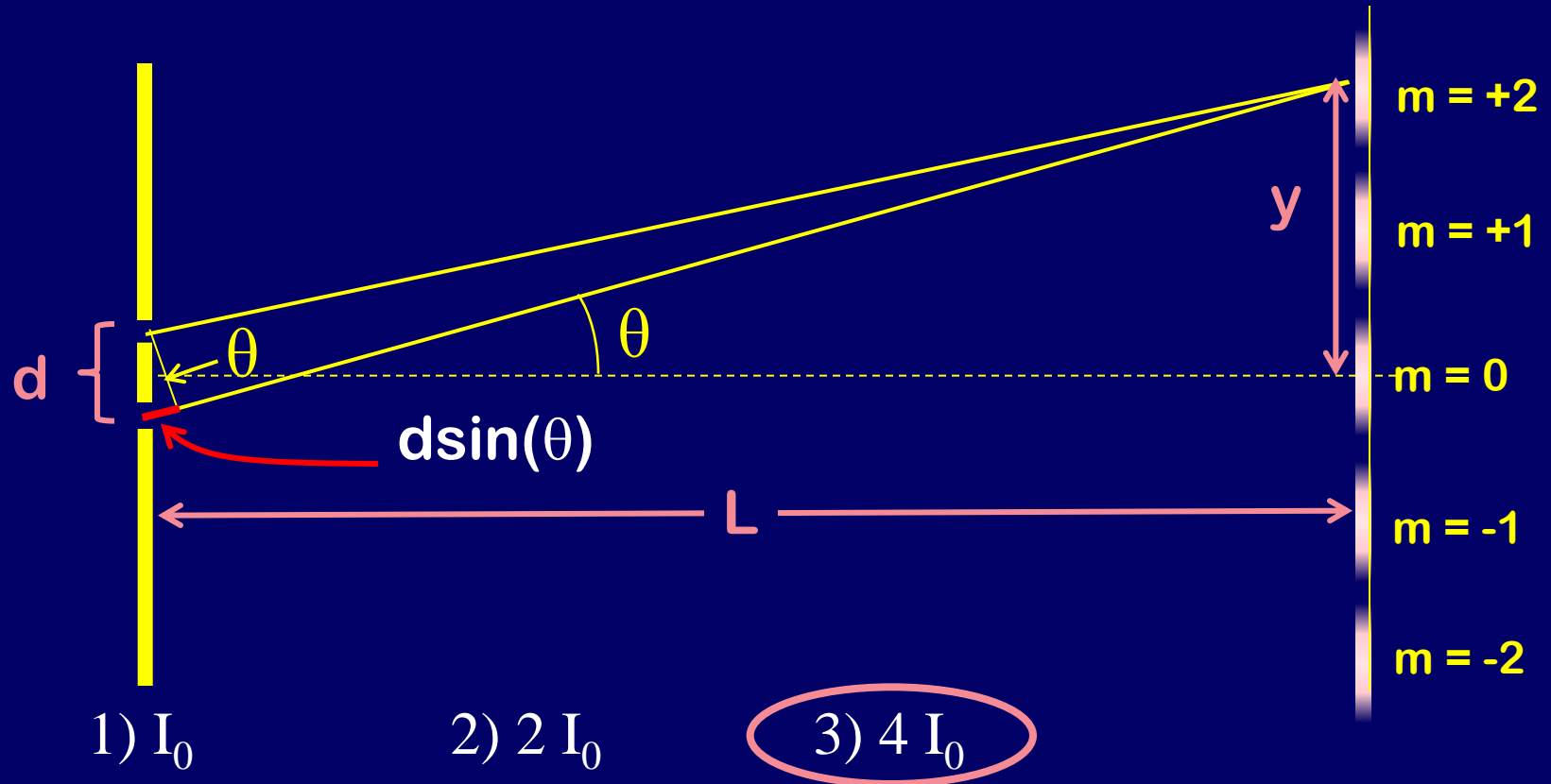
C) decreases
63%

Under water λ decreases so y decreases!



ACT: Intensity of fringes

The two waves are interfering constructively at the point shown. If the intensity of each is I_0 , what is the total intensity on screen?



Each slit contributes amplitude E_0 at screen. $E_{\text{tot}} = 2 E_0$.
But $I \propto E^2$. $I_{\text{tot}} = (2E_0)^2 = 4 E_0^2 = 4 I_0$

Checkpoint 1.2

In the Young double slit experiment, is it possible to see interference maxima when the distance between slits is smaller than the wavelength of light?

1) Yes

2) No

Need: $d \sin \theta = m \lambda \Rightarrow \sin \theta = m \lambda / d$

If $\lambda > d$ then $\lambda / d > 1$

so $\sin \theta > 1$

Not possible!

