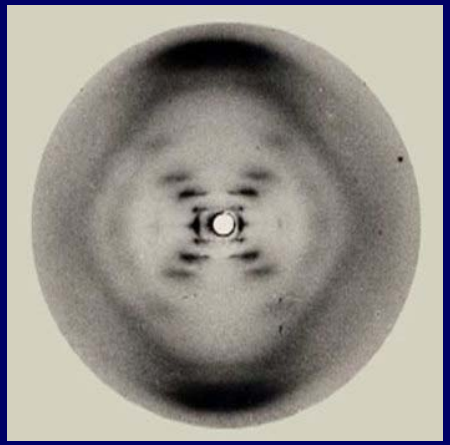
Physics 102: Lecture 20
Interference



Phys 102 recent lectures

Light as a wave

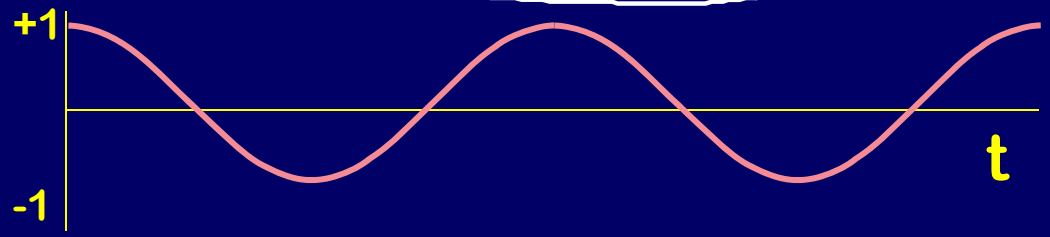
- Lecture 14 – EM waves
- Lecture 15 – Polarization
- Lecture 20 & 21 – Interference & diffraction

Light as a ray

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

Superposition

Constructive Interference



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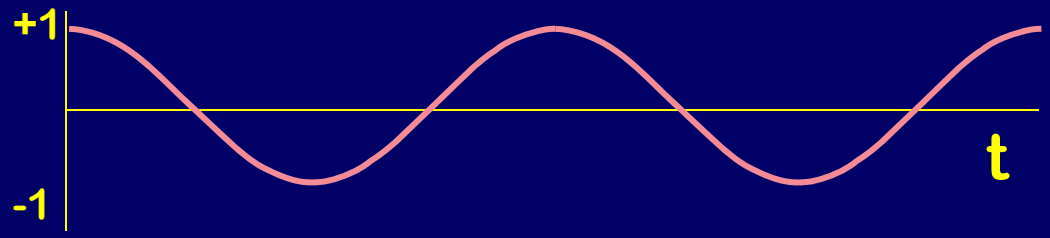
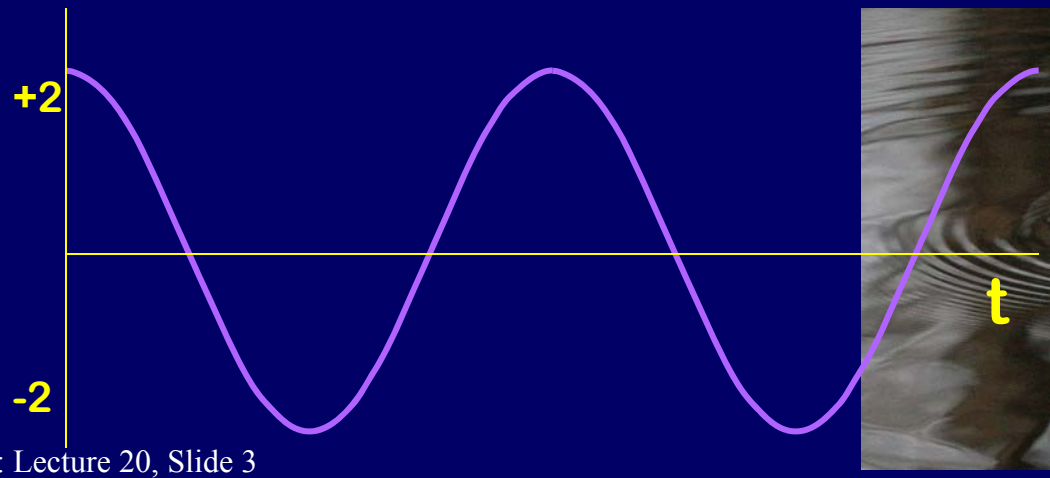
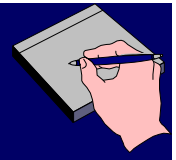


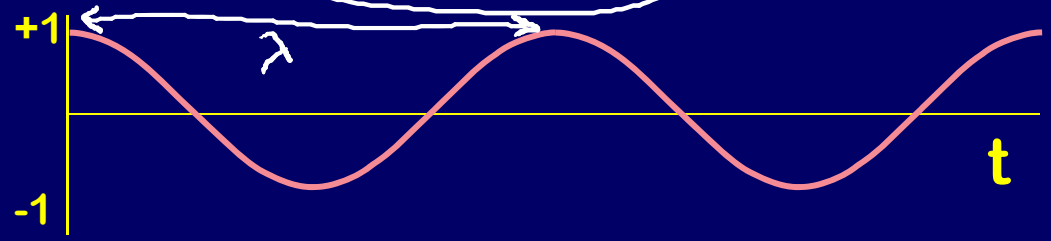
In Phase



Superposition



Destructive Interference



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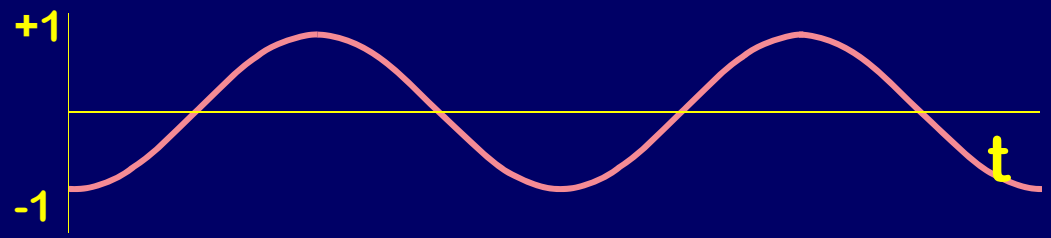
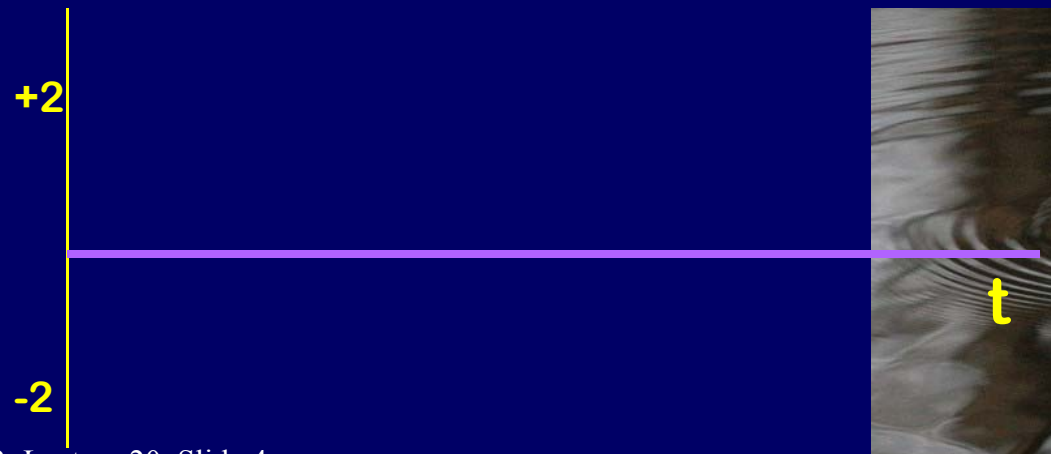
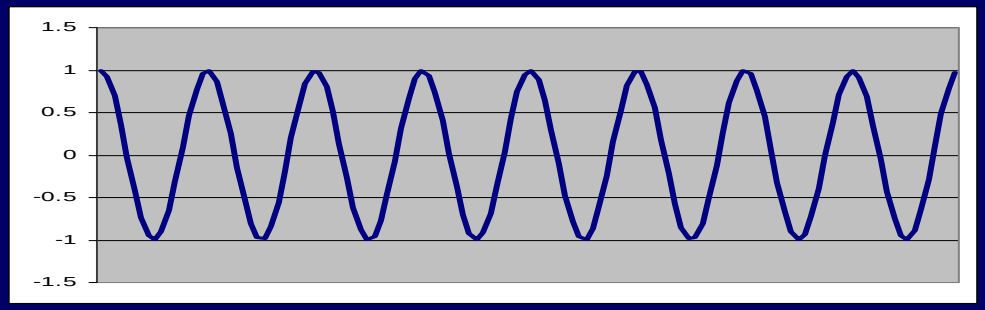


Out of Phase

180 degrees $\lambda/2$



ACT: Superposition



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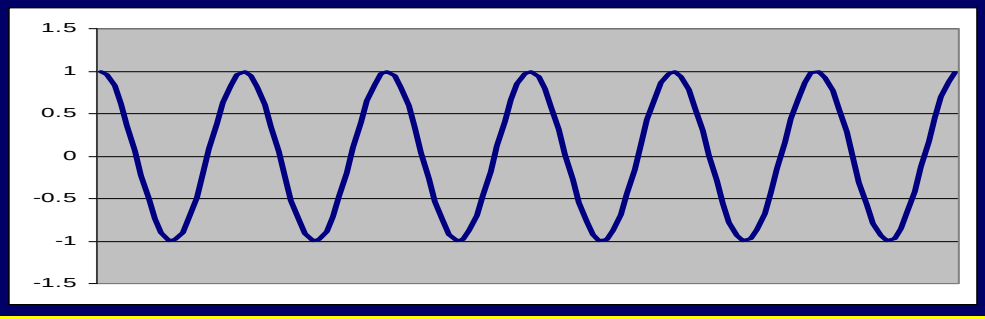
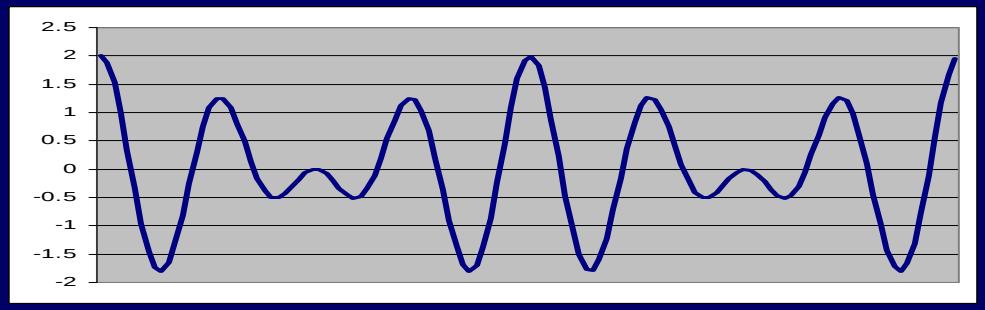
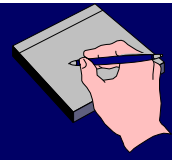


Different f or λ



1) Constructive **2) Destructive** **3) Neither**

Constructive/Destructive Interference Requirements



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

Destructive interference:

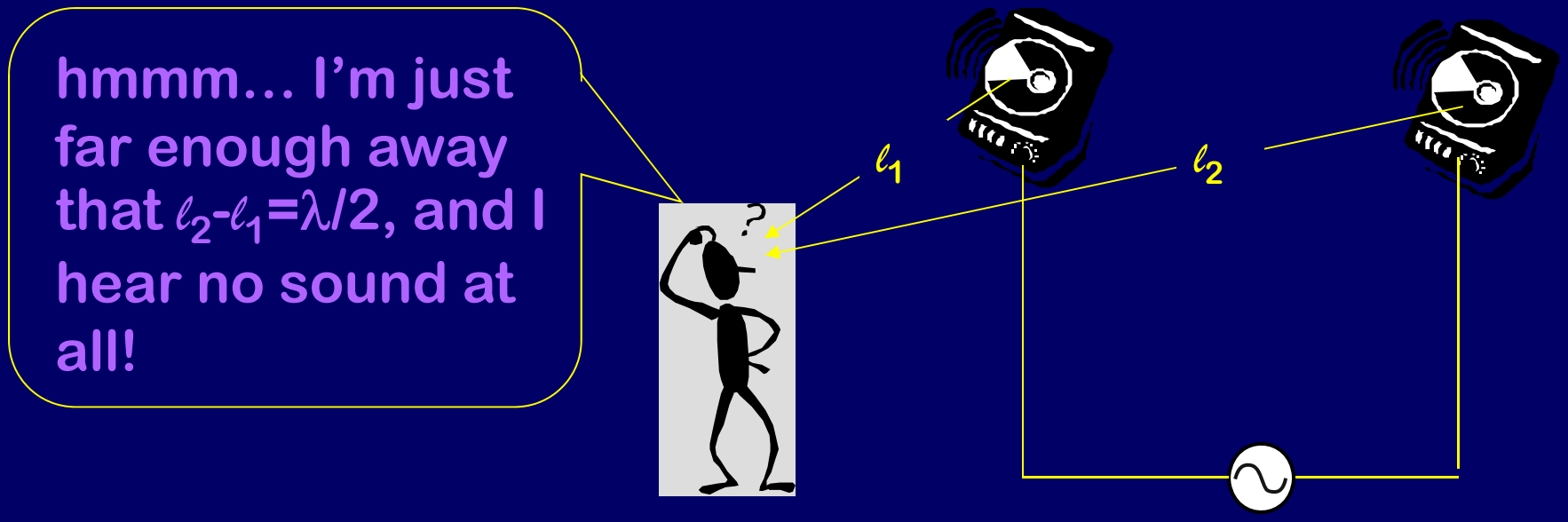
- **Waves are out of phase by 180°**
- **Path difference d between waves=** $\lambda/2, 3\lambda/2, 5\lambda/2, \ldots$
- $d/\lambda=\delta=1/2, 3/2, 5/2, \ldots$

Constructive interference

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

Demo: Interference for Sound …

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



Demo: Interference for Sound …

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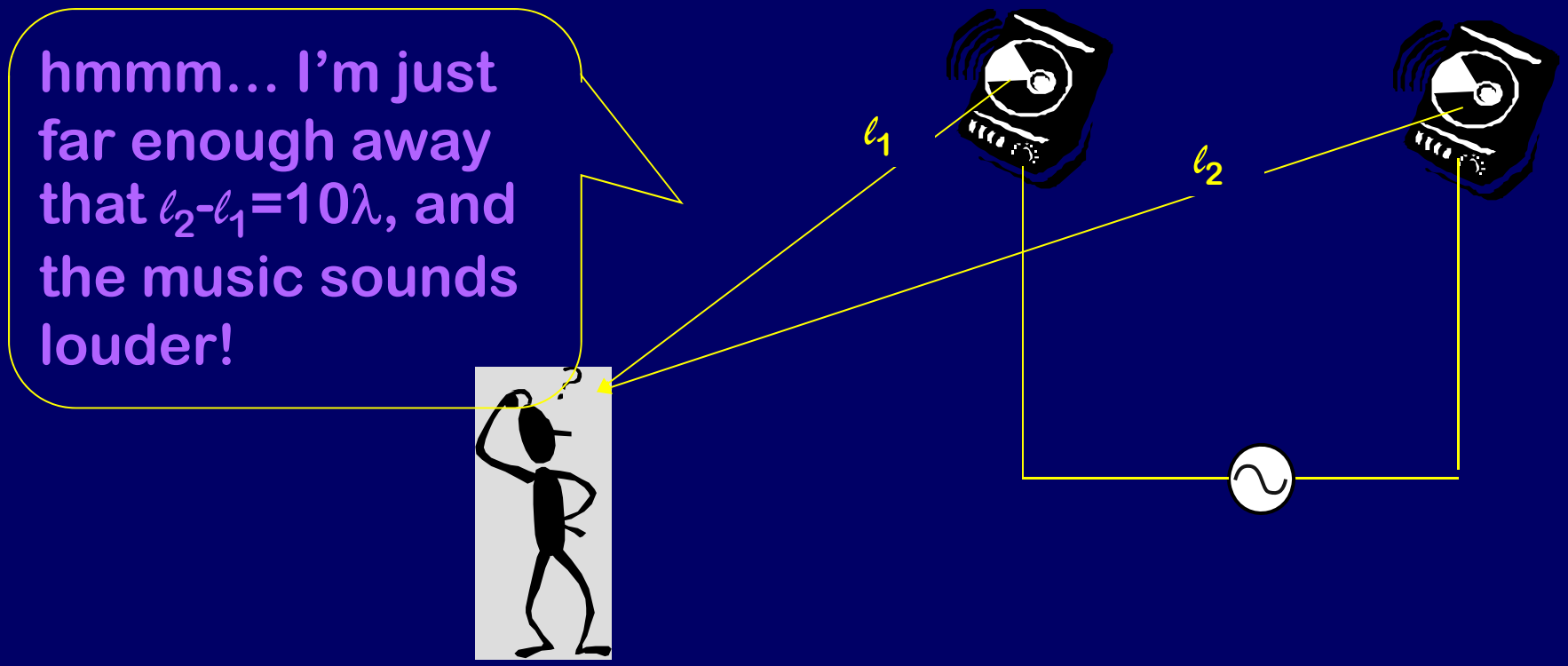
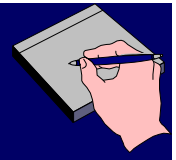




Interference for Light …

- 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

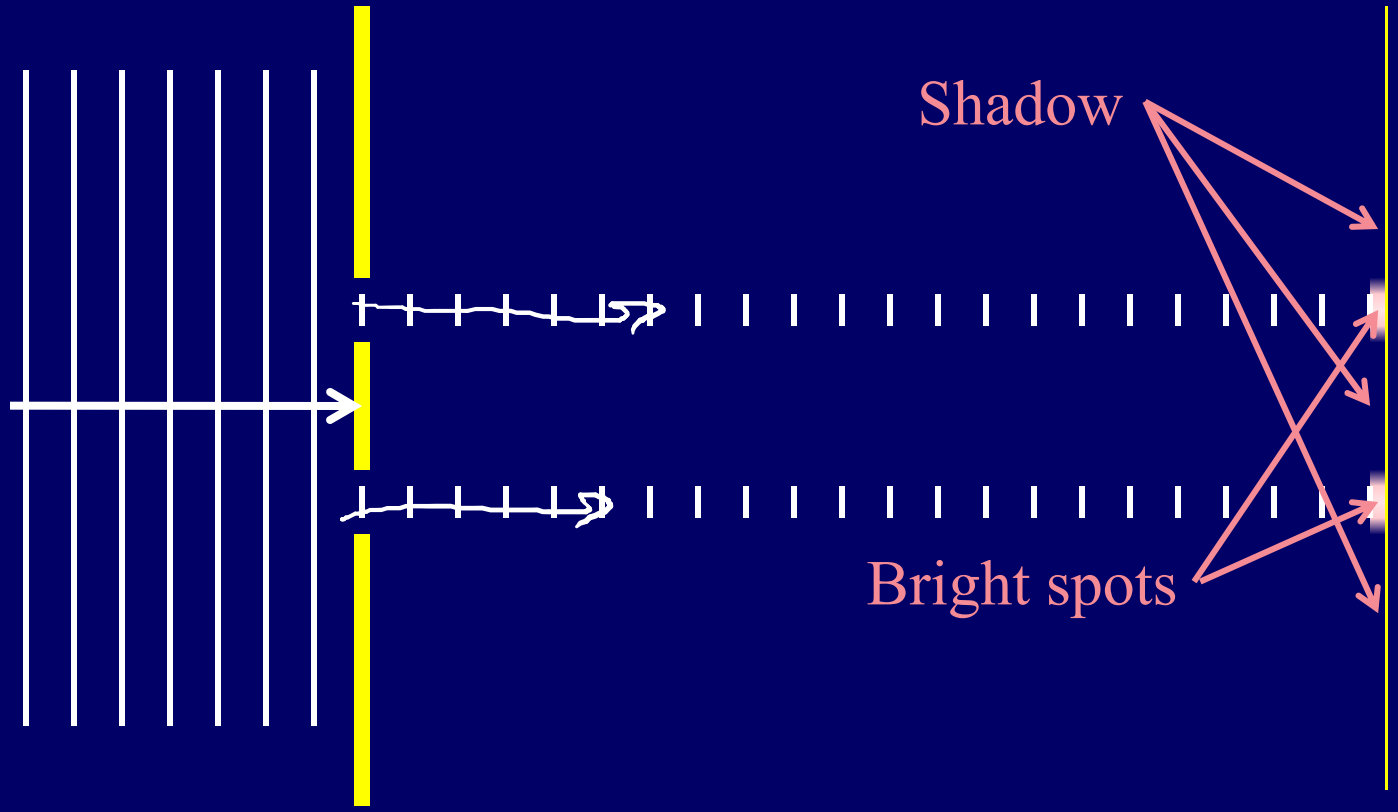
Next lecture

Young's double slit/rays

single λ

Monochromatic light travels through 2 slits onto a screen

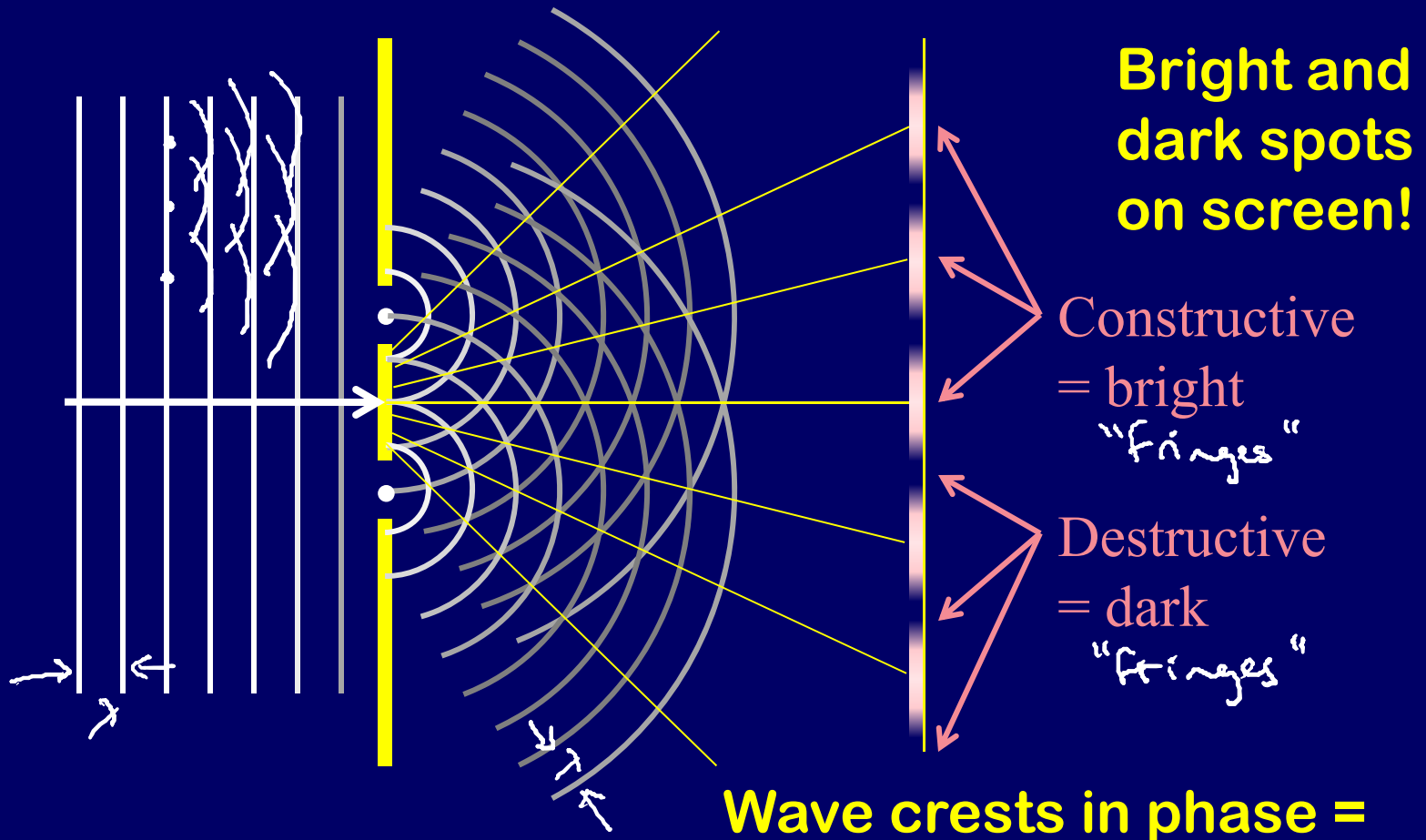
What pattern emerges on the screen?



This is <u>not</u> what is actually seen!

Young's double slit/Huygens

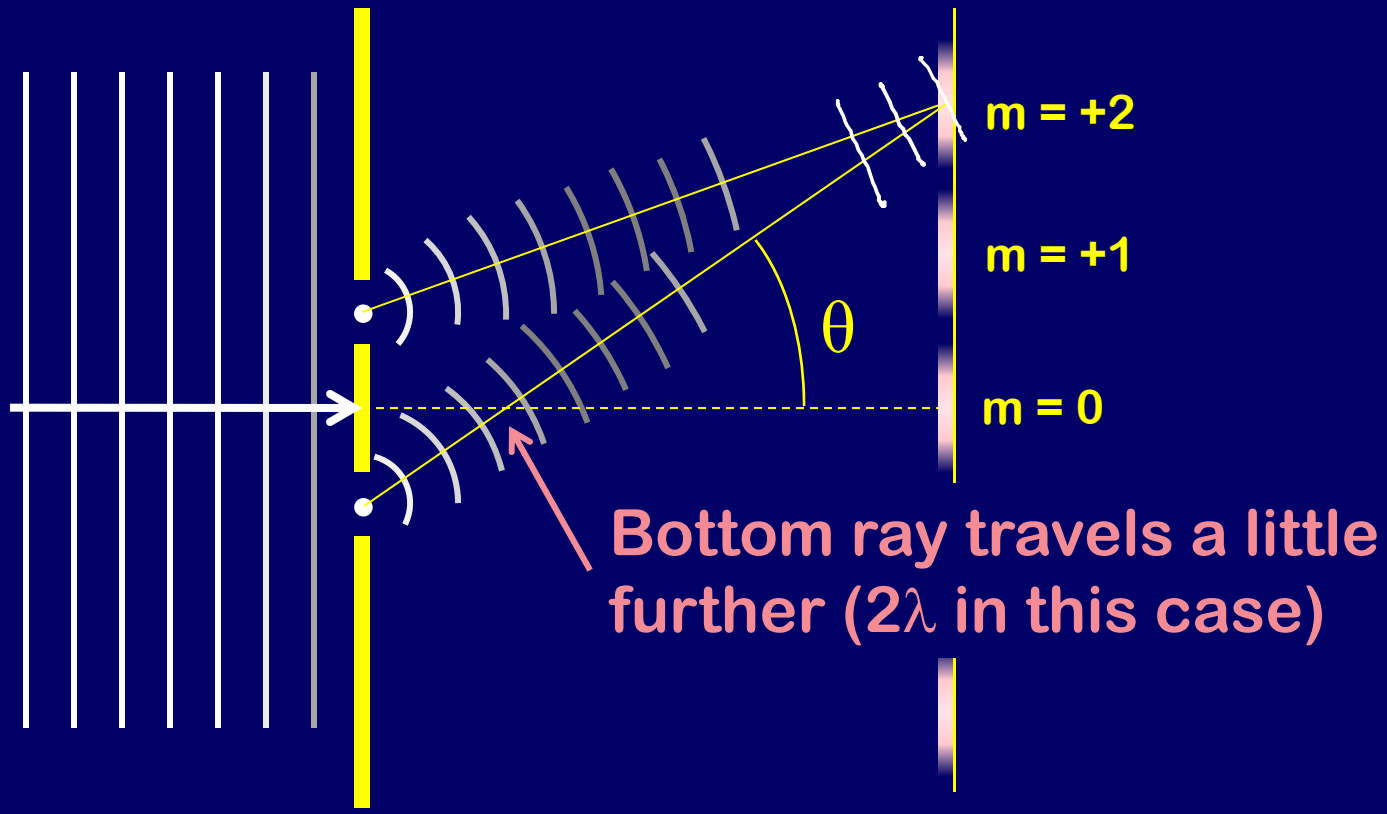
Recall Huygens' principle: Every point on a wave front acts as a source of tiny wavelets that move forward.



Wave crests in phase = constructive interference

Young's double slit: Key idea

Consider two rays traveling at an angle θ:

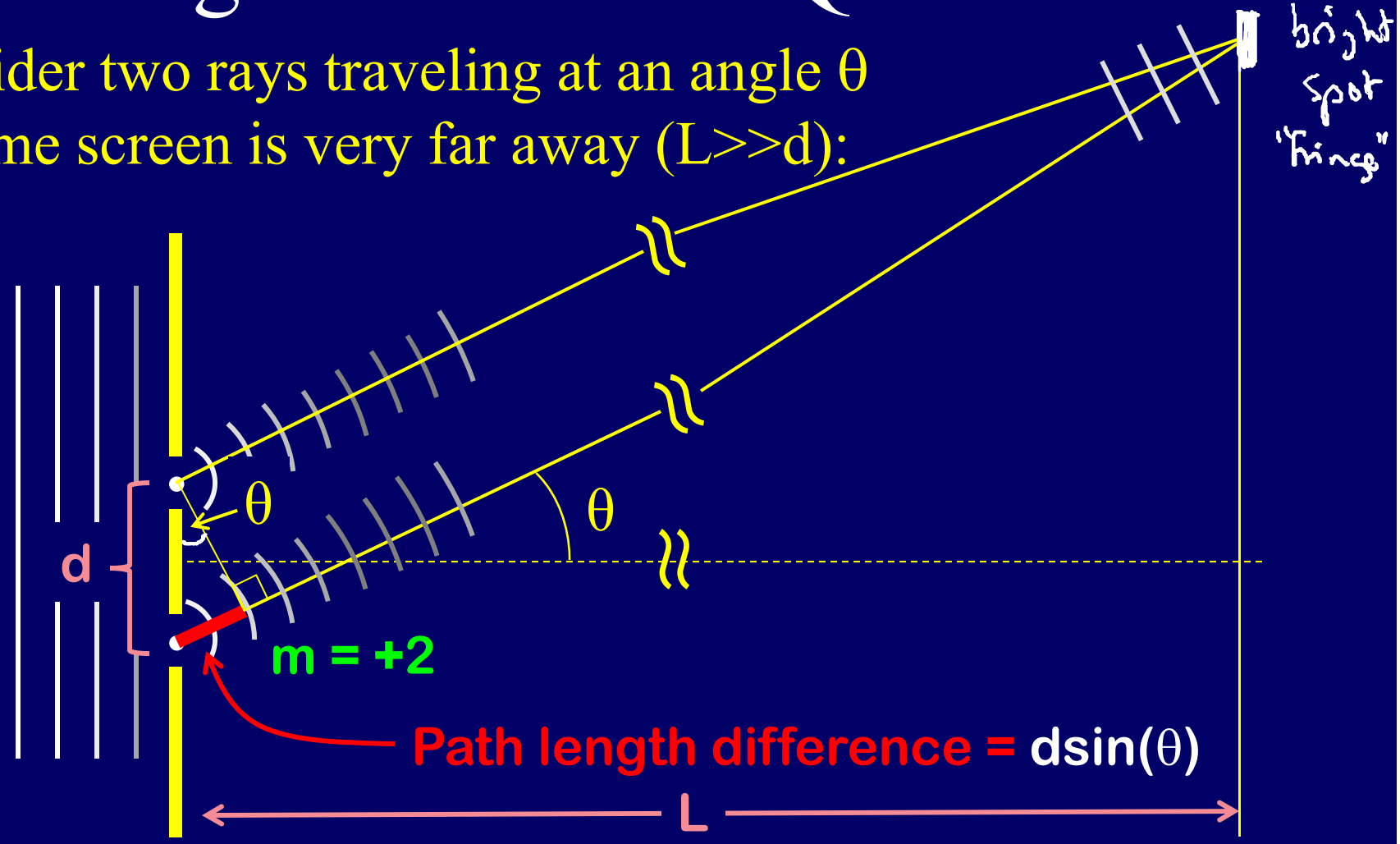


Key for interference is this small extra distance.

Young's double slit: Quantitative

Consider two rays traveling at an angle θ

Assume screen is very far away (L>>d):



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

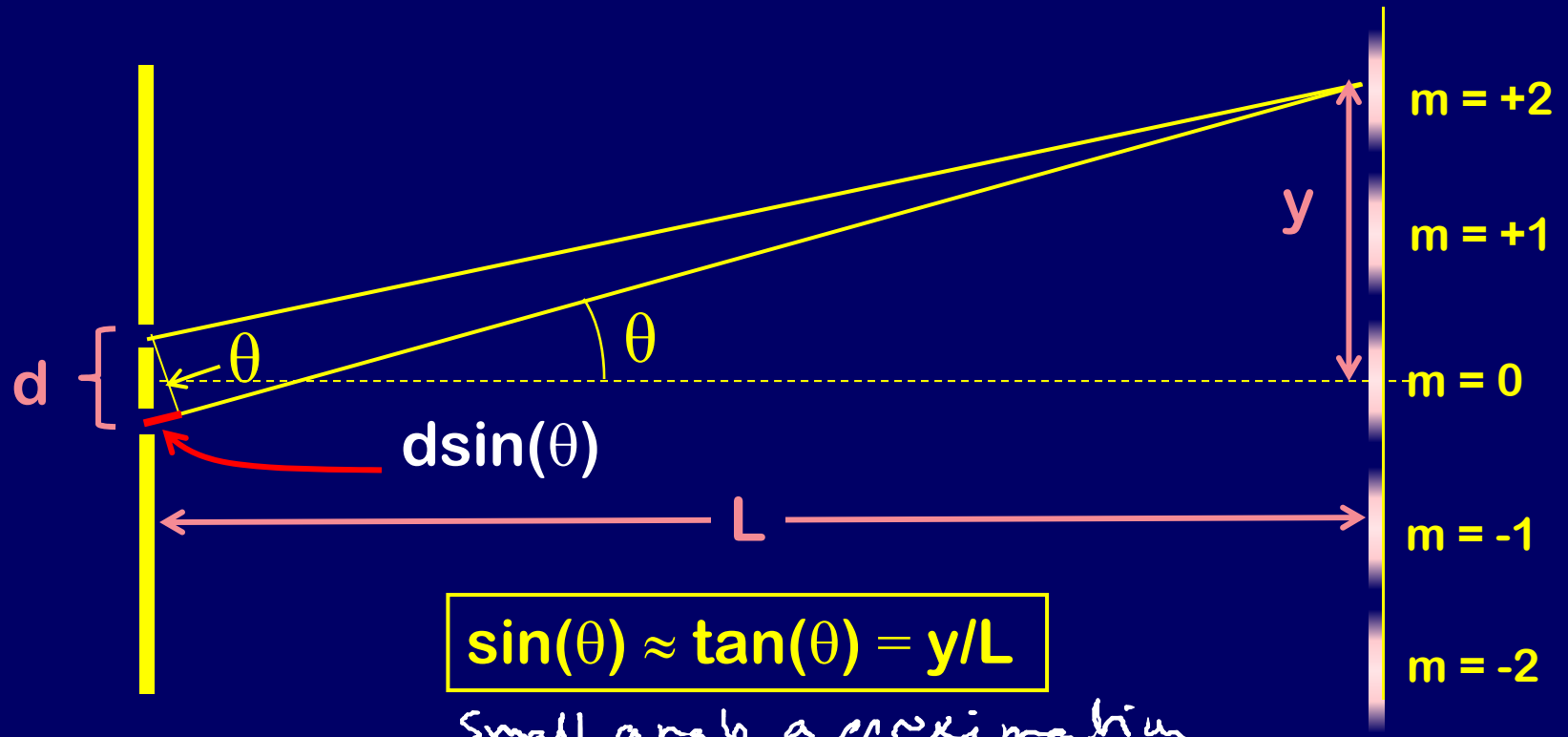
Destructive: $d\sin(\theta) = (m+1/2)\lambda$

where m = 0, ±1, ±2

Need $\lambda < d$

Young's double slit: Quantitative

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



$\sin(\theta) \approx \tan(\theta) = y/L$

small angle approximation

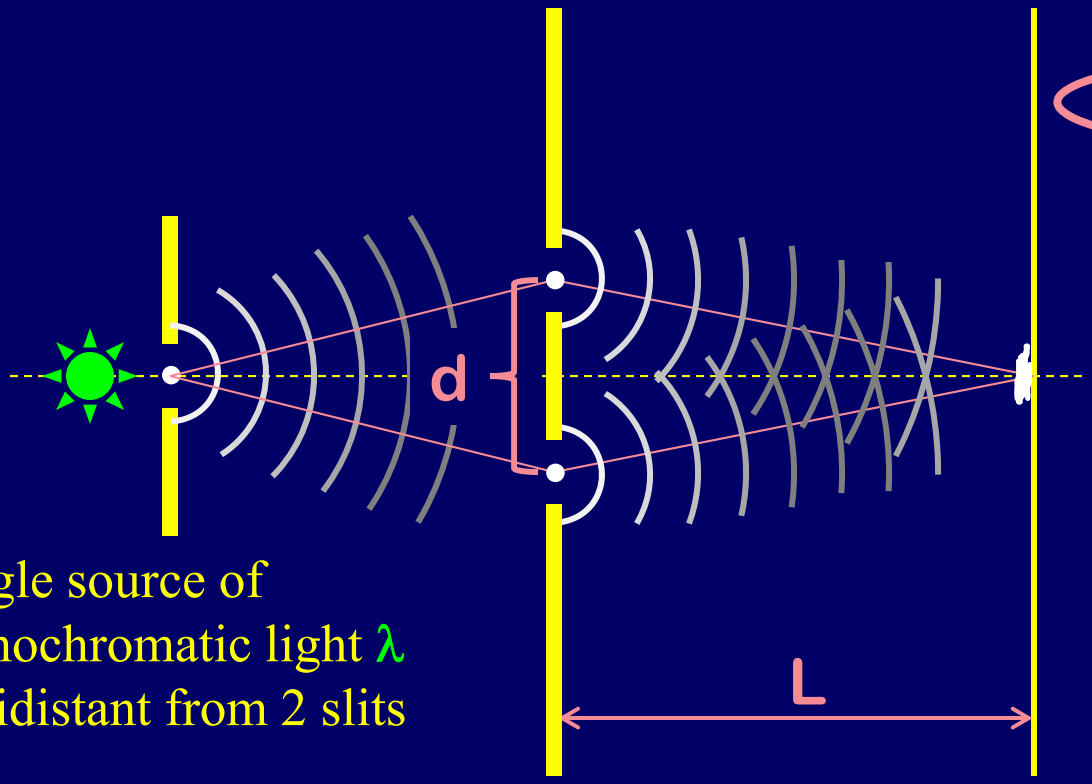
Constructive: $d\sin(\theta) = m\lambda$ $\quad y \approx m\lambda L/d$

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

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

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.

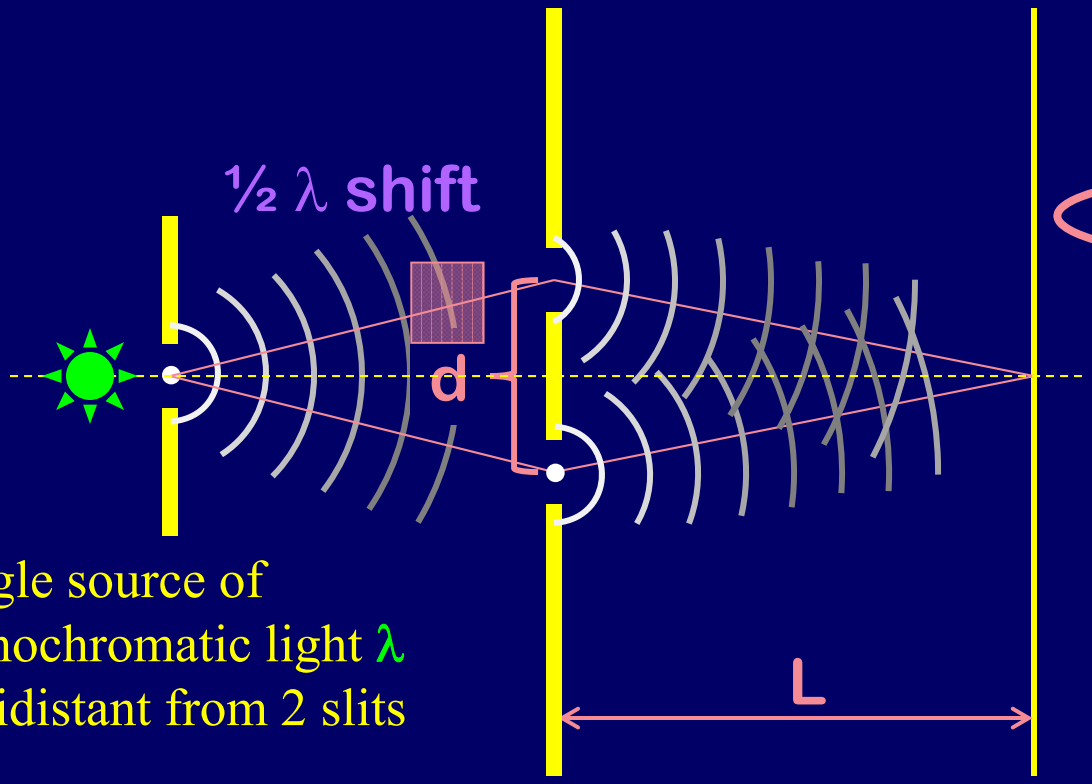
Single source of monochromatic light λ equidistant from 2 slits

2 slits separated by d

Screen a distance L from slits

ACT/Checkpoint 1.1

The experiment is modified so that one of the waves has its phase shifted by ½ λ. Now, the interference behind the slits will be:



A. Constructive

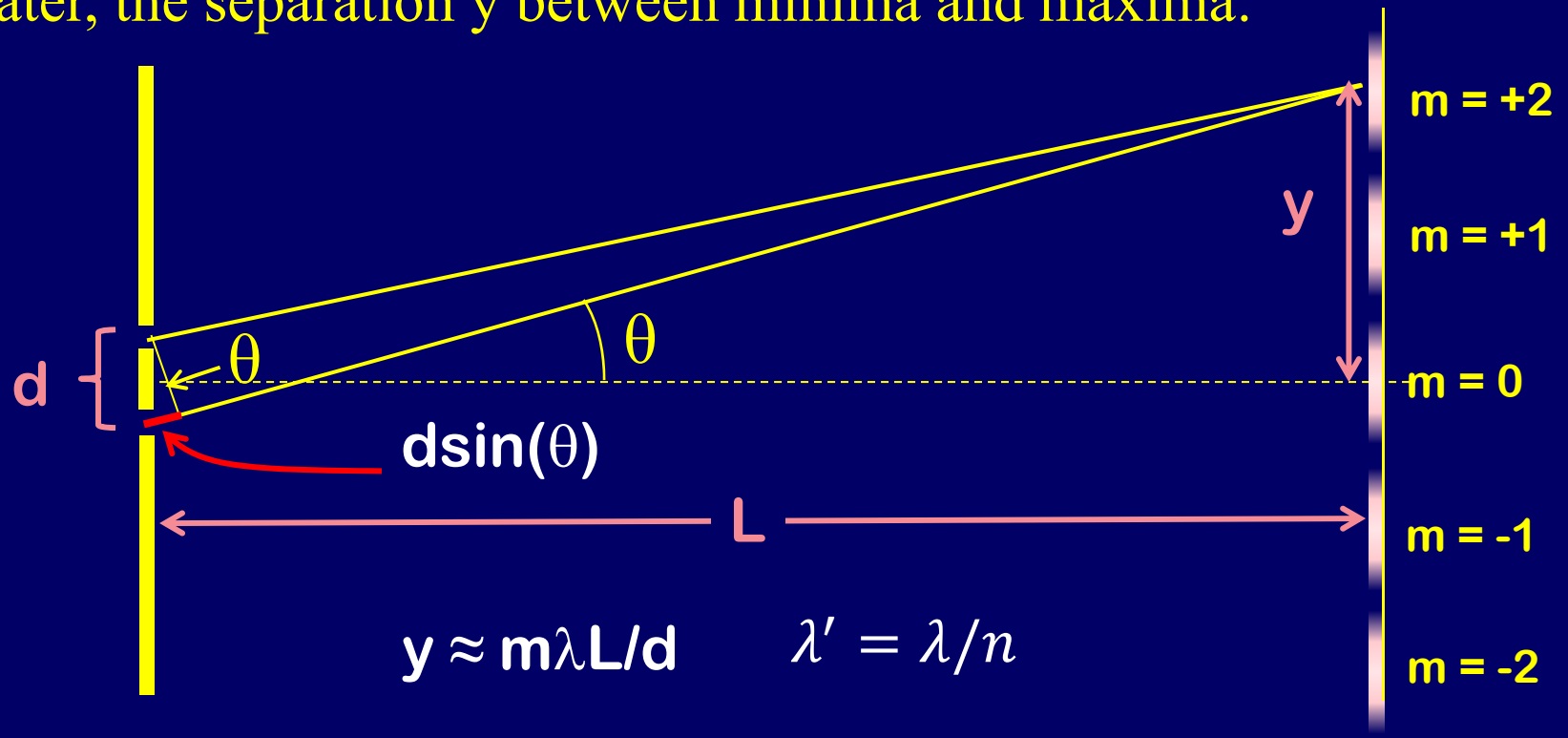
B. Destructive

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 19%

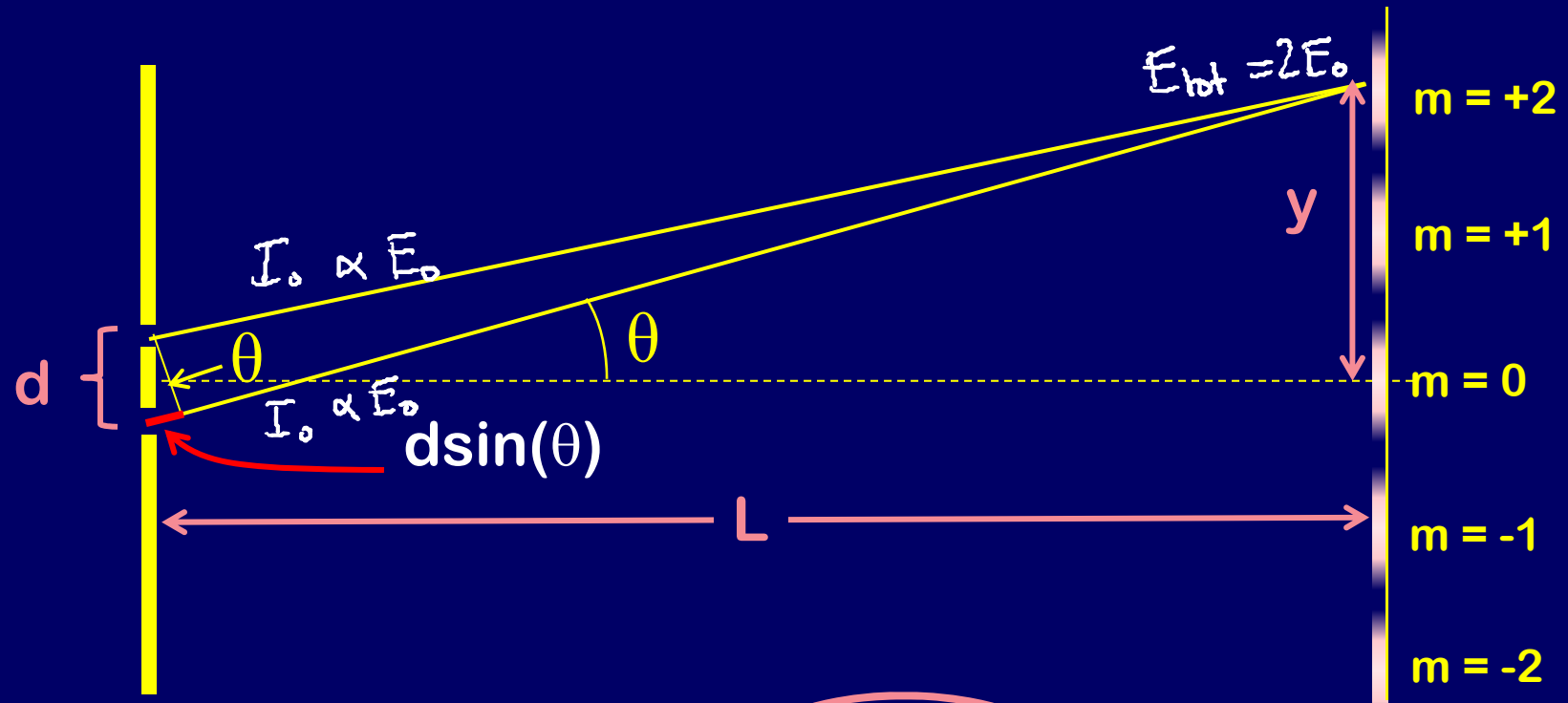
B) same 26%

C) decreases 55%

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?



1) I_0 2) $2\ I_0$ 3) $4\ I_0$

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

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

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

so $\sin\theta > 1$

Not possible!