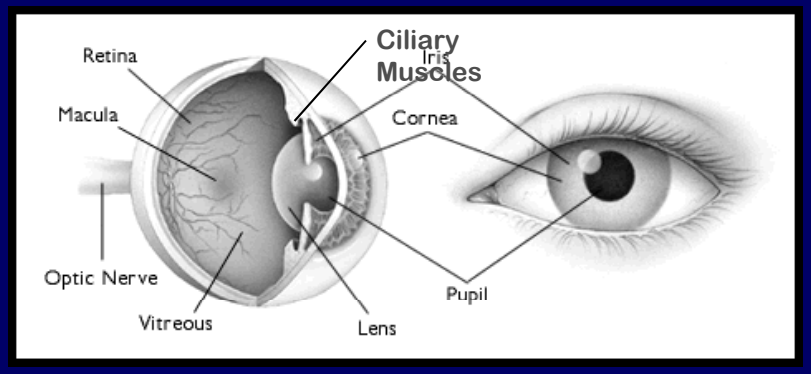
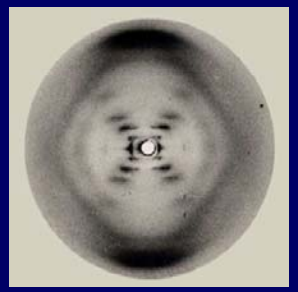
Exam 3 two weeks from today

- How do you study?
  - Start studying now! (cramming DOES NOT work)
  - Emphasize understanding concepts & problem solving, NOT memorization
  - Review lecture notes, problem solver summary
  - Understand formula sheet (i.e. when to use and when NOT to use an equation) & know what each symbol means
- Also, James Scholar proposals due April 7

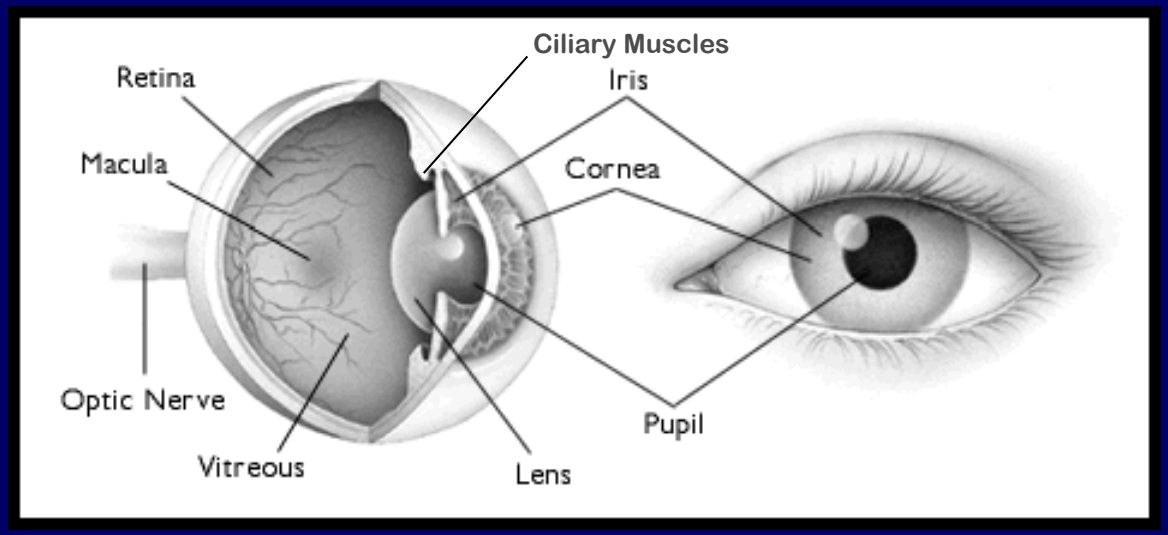
Physics 102: Lecture 19 & 20
Your Eye & Interference





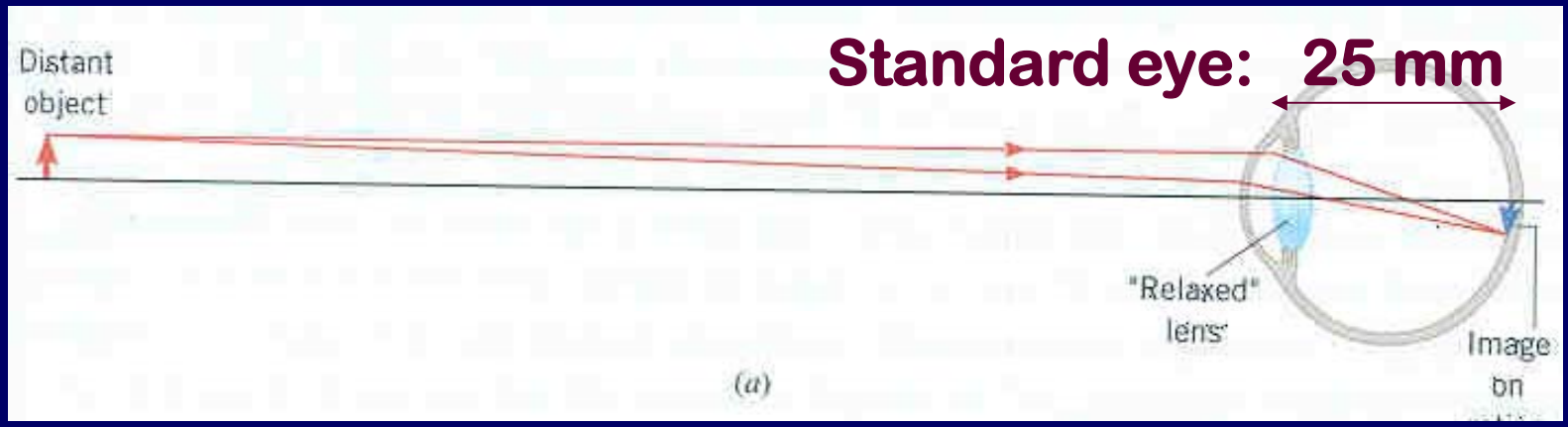
The Eye

- One of first organs to develop
- ~100 million receptors
- Sensitive to a few photons!
- Eye's lens creates image on retina
  - Lens can change shape (changes *f*)



Example

Eye (Relaxed)



Determine the focal length of your eye when looking at an object far away.

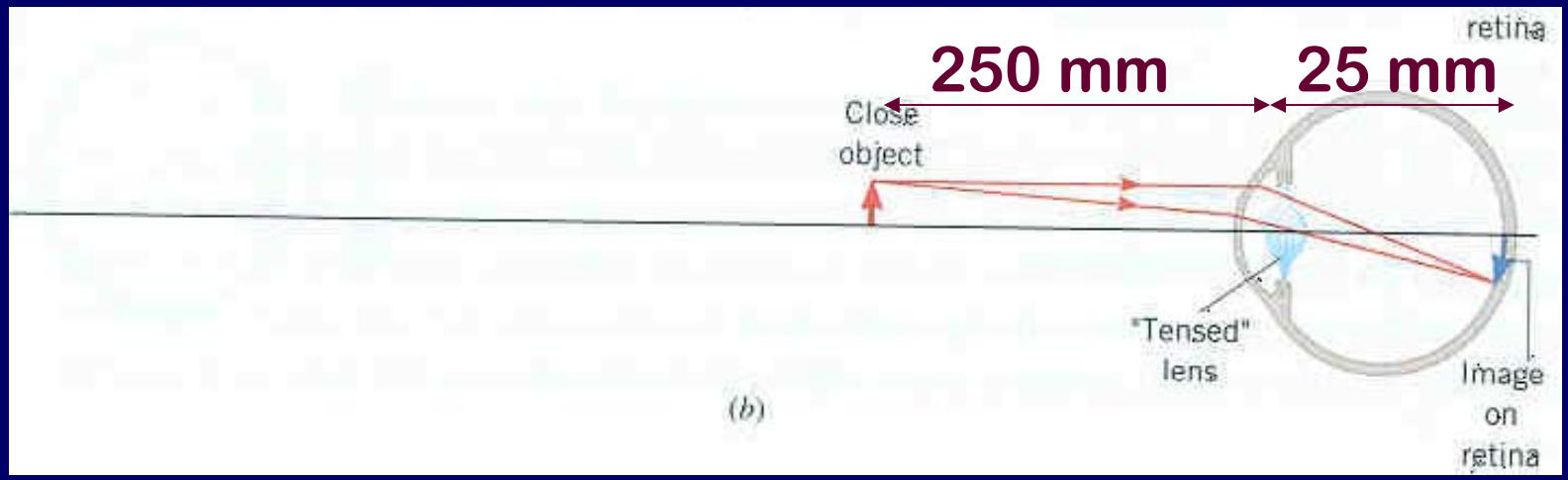
Object is far away: $d_o = \infty$

Want image at retina: $d_i = 25mm$

$$\frac{1}{\infty} + \frac{1}{25\ \text{mm}} = \frac{1}{f}$$

$$f_{relaxed} = 25\ \text{mm}$$

Eye (Tensed)



Determine the focal length of your eye when looking at an object up close (25 cm). "Near point"

$$\frac{1}{250\,\text{mm}} + \frac{1}{25\,\text{mm}} = \frac{1}{f}$$

Object is up close:

$$d_o = 25cm = 250mm$$

$$f_{tense} = 22.7\ \text{mm}$$

Want image at retina: $d_i = 25mm$

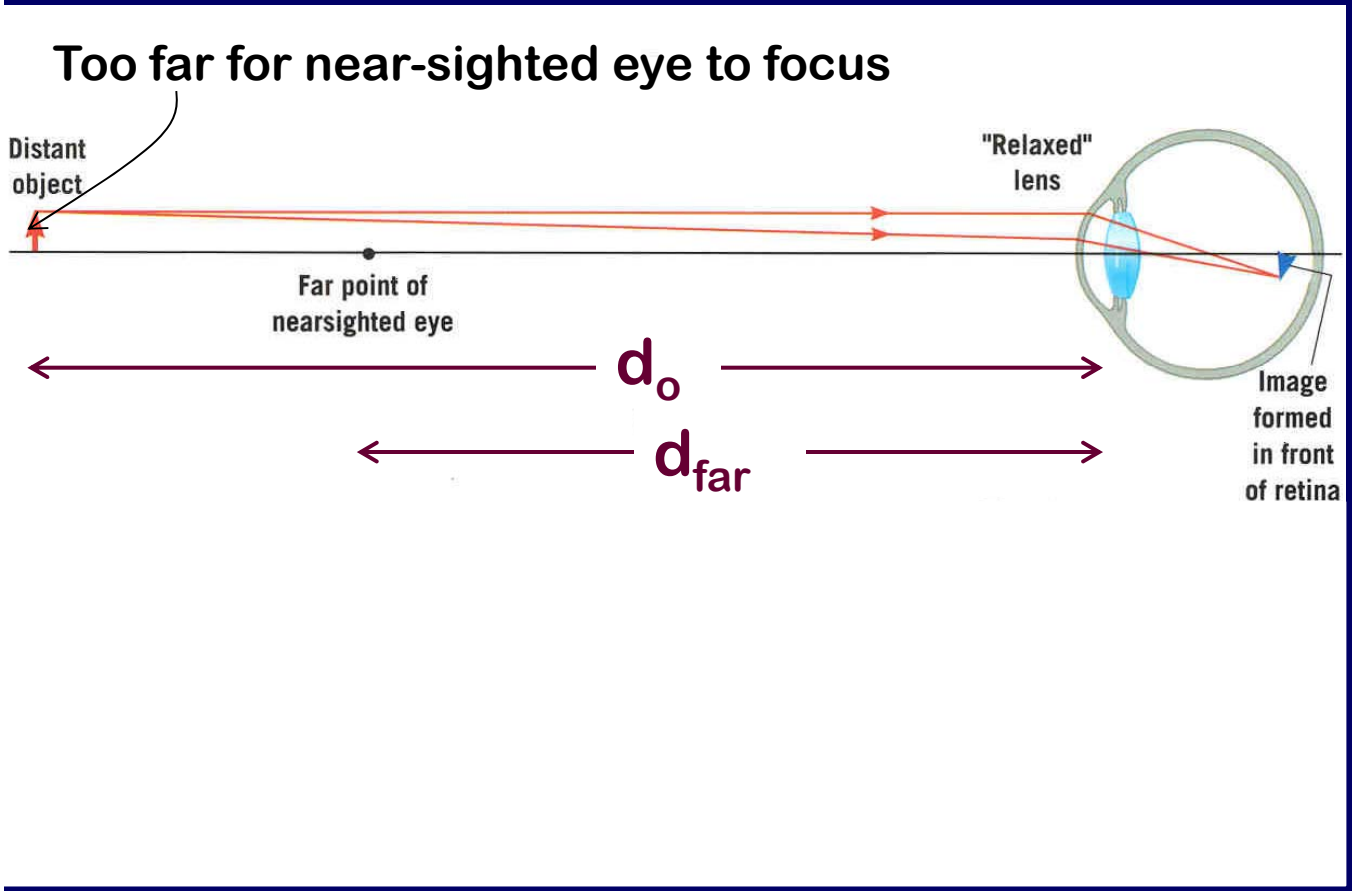
$$f_{relaxed} = 25\ \text{mm}$$

Near Point, Far Point

- Eye's lens changes shape (changes *f*)
  - Object at any d_o should have image be at retina (d_i = approx. 25 mm)
- Can only change shape so much
- "Near Point"
  - Closest d_o where image can be at retina
  - Normally, ~25 cm (if far-sighted then further)
- "Far Point"
  - Furthest d_o where image can be at retina
  - Normally, infinity (if near-sighted then closer)

If you are nearsighted...

(far point is too close)



Example

$$\frac{1}{d_o} + \frac{1}{-d_{far}} = \frac{1}{f_{lens}}$$

$$\frac{1}{\infty} + \frac{1}{-d_{far}} = \frac{1}{f_{lens}}$$

$$f_{lens} = - d_{far}$$

Diverging lens!

Want to have (virtual) image of distant object, $d_o = \infty$, at the far point, $d_i = -d_{far}$.

Refractive Power of Lens

Diopter = 1/f

where f is focal length of lens in meters.

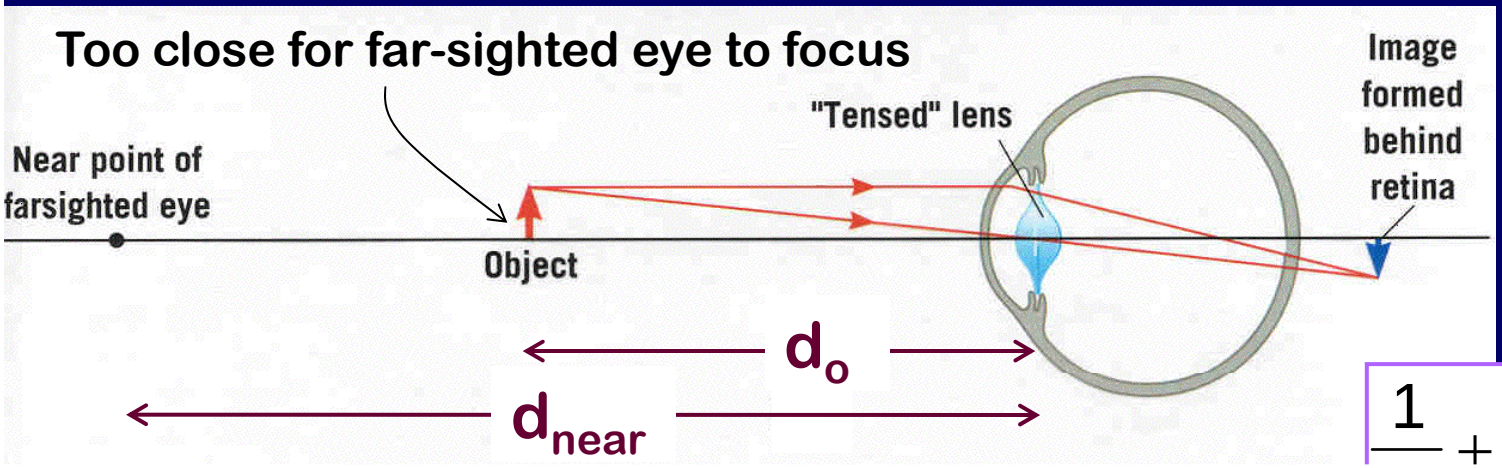
Example:

- Prescription reads -6.5 diopters
- f_{lens} = -1/6.5 = -0.154 m = -15.4 cm (a diverging lens)
- d_{far} = 15.4 cm (!)

$$f_{lens} = - d_{far}$$

If you are farsighted...

(near point is too far)



$$\frac{1}{f_{lens}} = \frac{1}{-d_{near}} + \frac{1}{25}$$

$$\frac{1}{f_{lens}} = \frac{1}{-d_{near}} + \frac{1}{25}$$

When object is at d_o, lens must create an (virtual) image at $-d_{near}$

$d_{near} > 25\,cm$

$f_{lens} > 0$

Converging lens!

Example

Farsightedness

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f_{lens}}$$

- Near point $d_{near} > 25$ cm
- To correct, produce virtual image of object at $d_0 = 25$ cm to the near point ($d_i = -d_{near}$)

$$\frac{1}{d_o}+\frac{1}{-d_{near}}=\frac{1}{f_{lens}} \quad \Rightarrow \quad \frac{1}{25}+\frac{1}{-d_{near}}=\frac{1}{f_{lens}}$$

Example:

- **Near prescription reads +2.5 diopters**
- **f_{lens} = +1/2.5 = 0.4 m = 40 cm**
- **therefore d_{near} = 67 cm** > 25 cm

Phys 102 recent lectures

Light as a wave

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

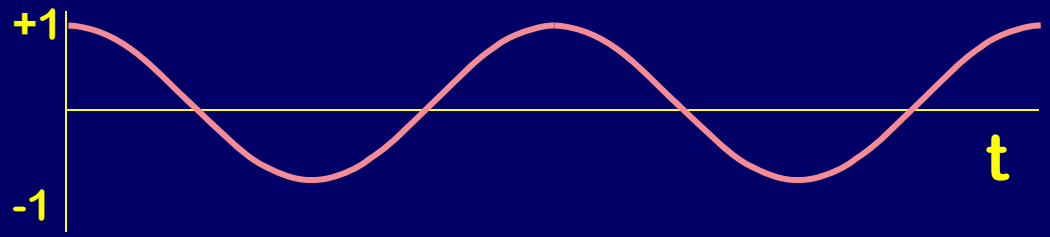
Light as a ray

object $\gg \lambda$

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

Superposition

Constructive Interference



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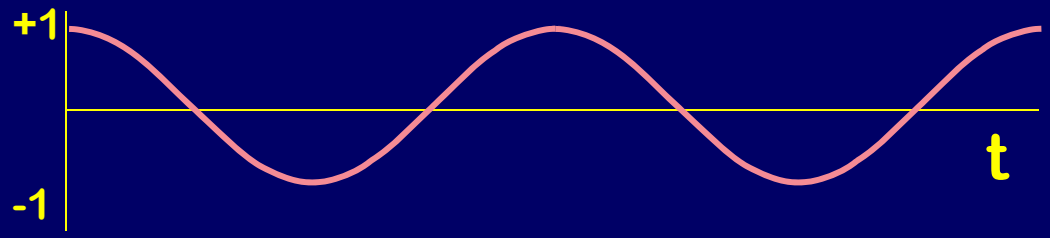
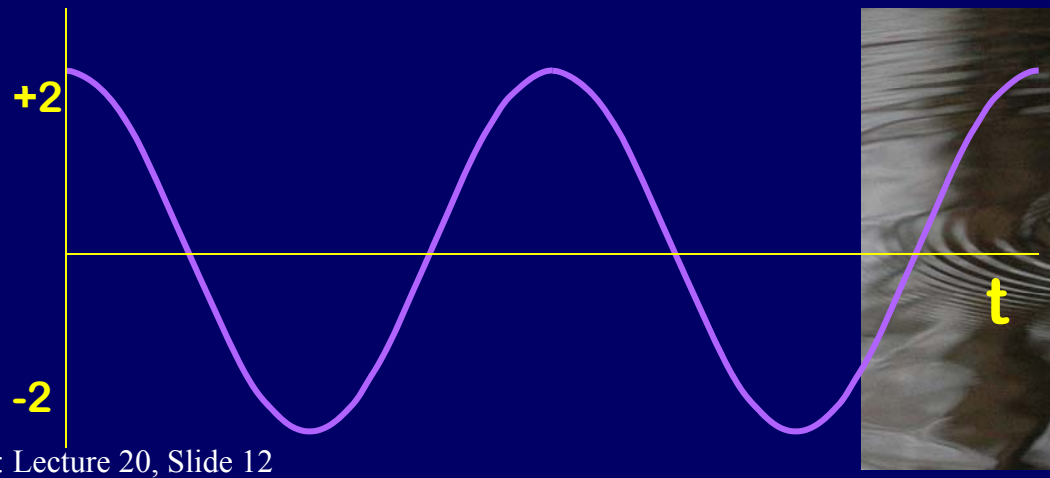
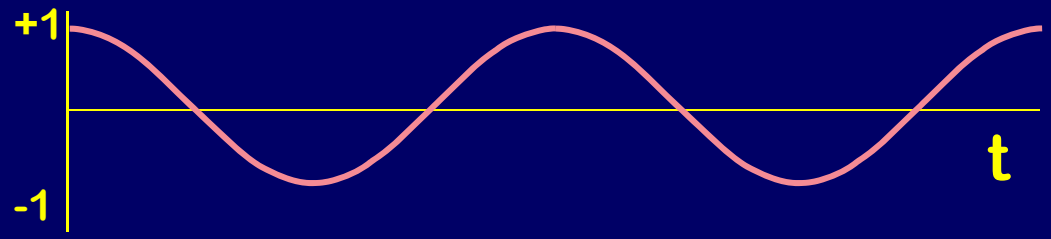


In Phase



Superposition

Destructive Interference



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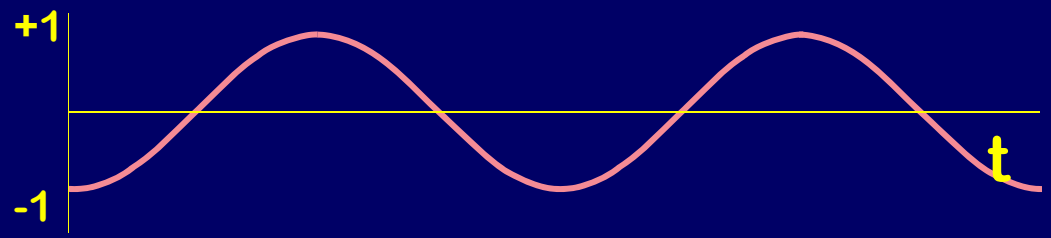
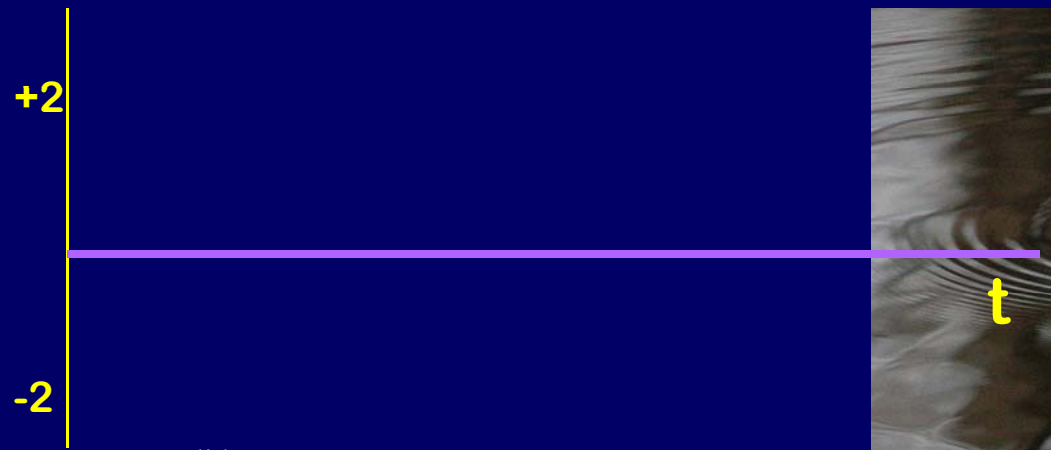
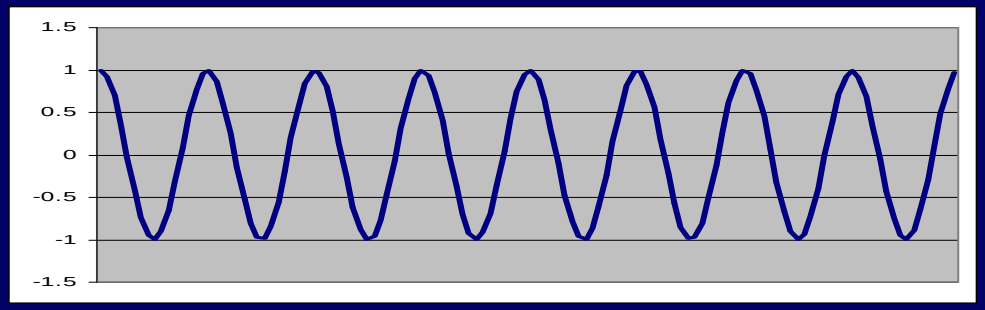


Out of Phase

180 degrees OR $\lambda/2$



ACT: Superposition



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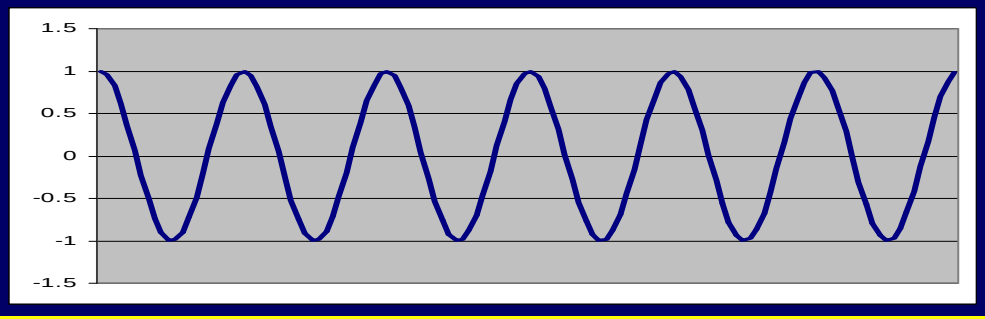
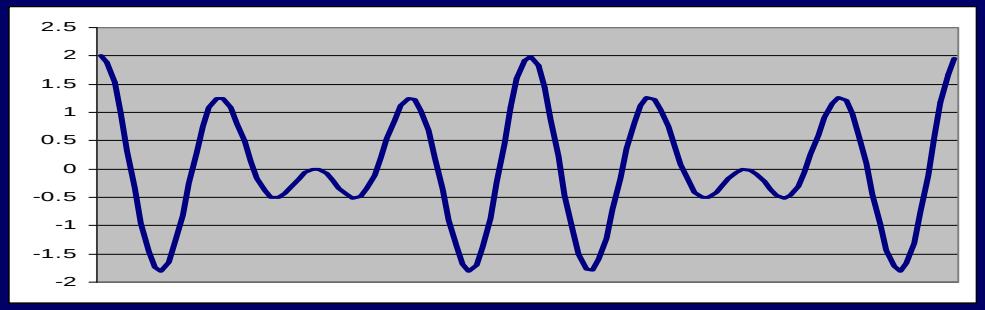
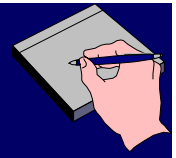


Different f



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:

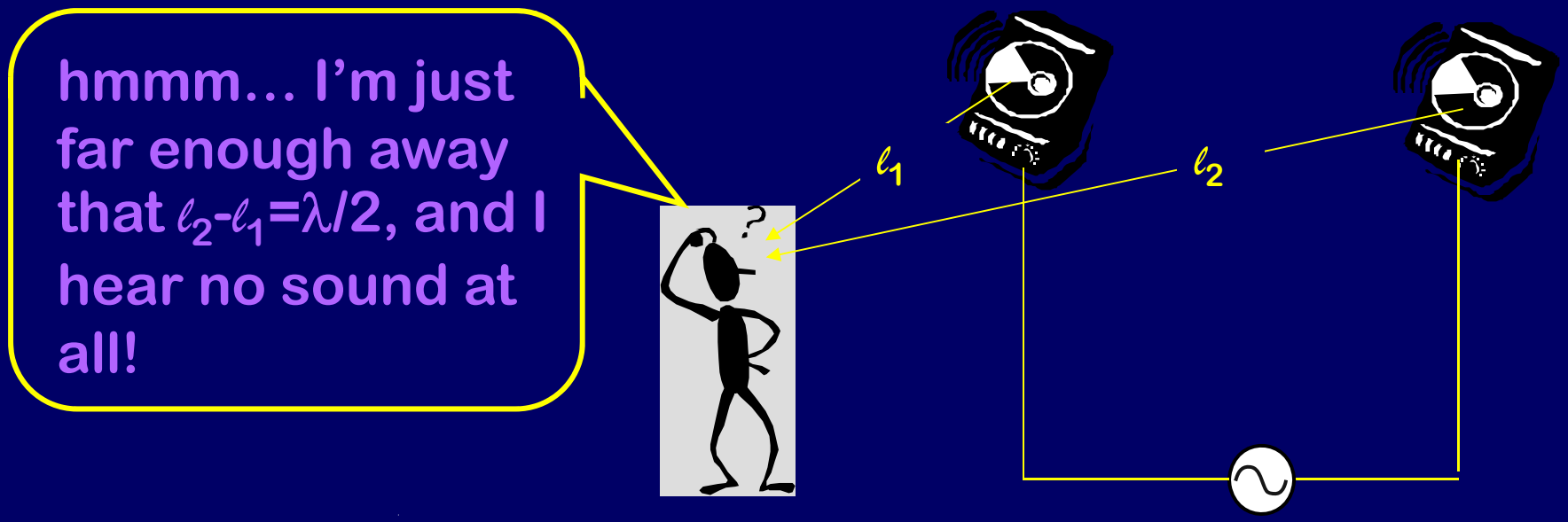
- Waves are out of phase by 180°
- Path difference d between waves = $\lambda/2$, $3\lambda/2$, $5\lambda/2$, …
- $d/\lambda = \delta = 1/2, 3/2, 5/2, \ldots$

Constructive interference:

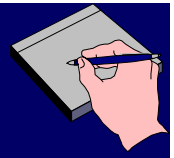
- Waves are in phase
- Path difference d between waves = 0, λ, 2λ, 3λ, ...
- $d/\lambda = \delta = 0, 1, 2, \ldots$

Demo: Interference for Sound …

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



PhET



Interference for Light …

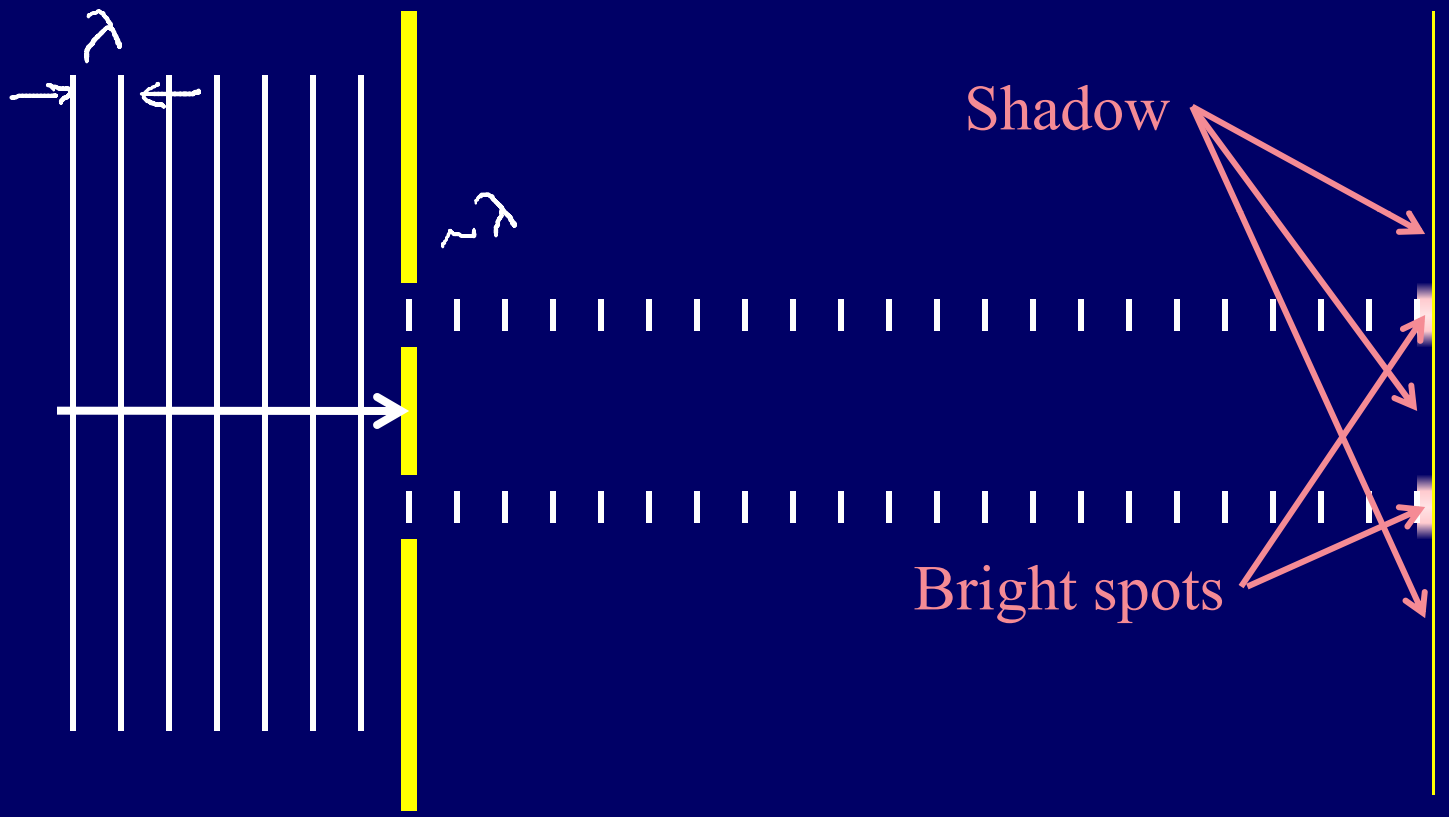
- Either use single-frequency lasers, or…
- Or microwave / radio-frequency sources, or…
- Need two waves from single source taking two different paths
  - Two slits
  - Reflection (thin films)
  - Diffraction

Today's lecture

Next lecture

Young's double slit/rays

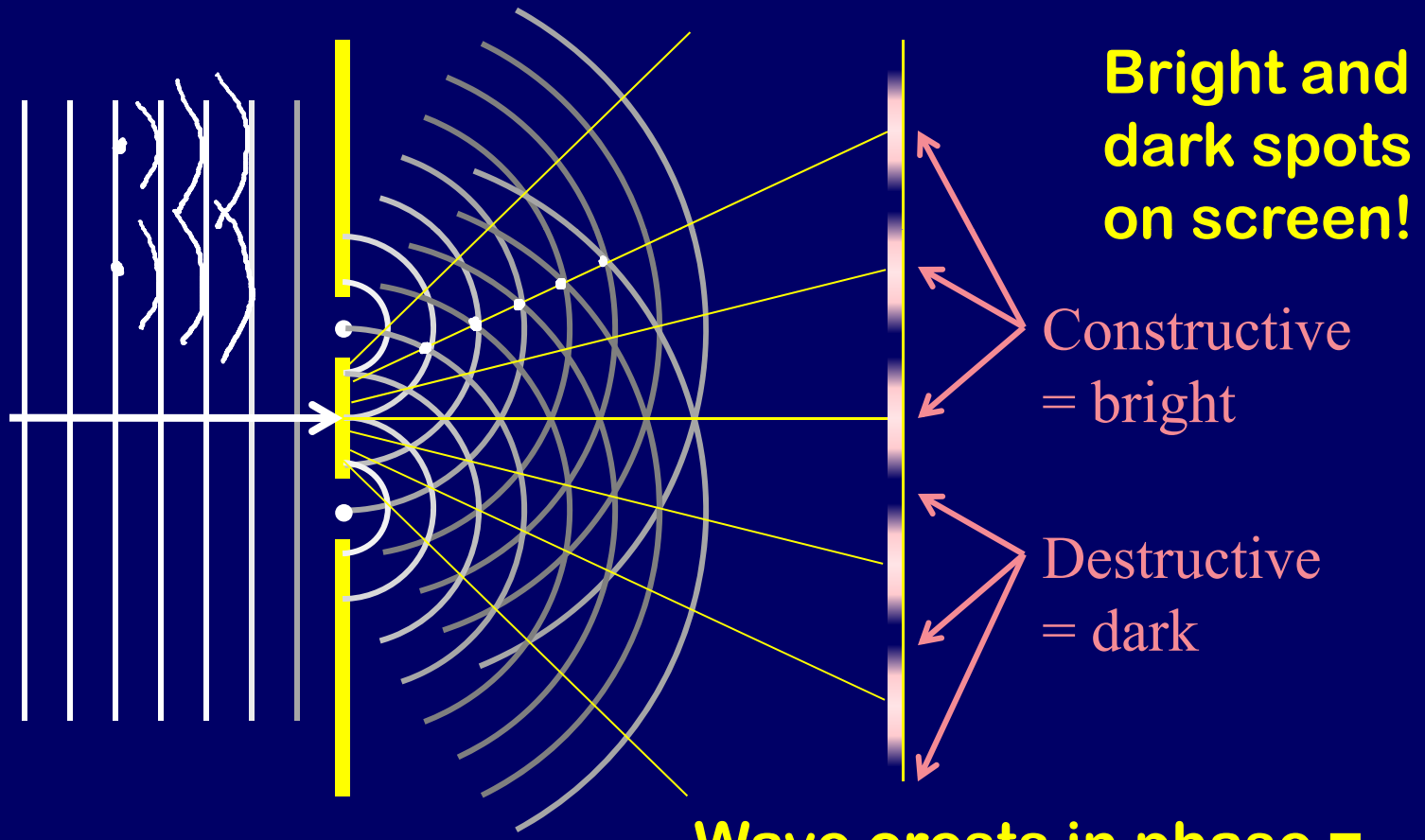
Monochromatic light travels through 2 slits onto a screen
What pattern emerges on the screen?



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

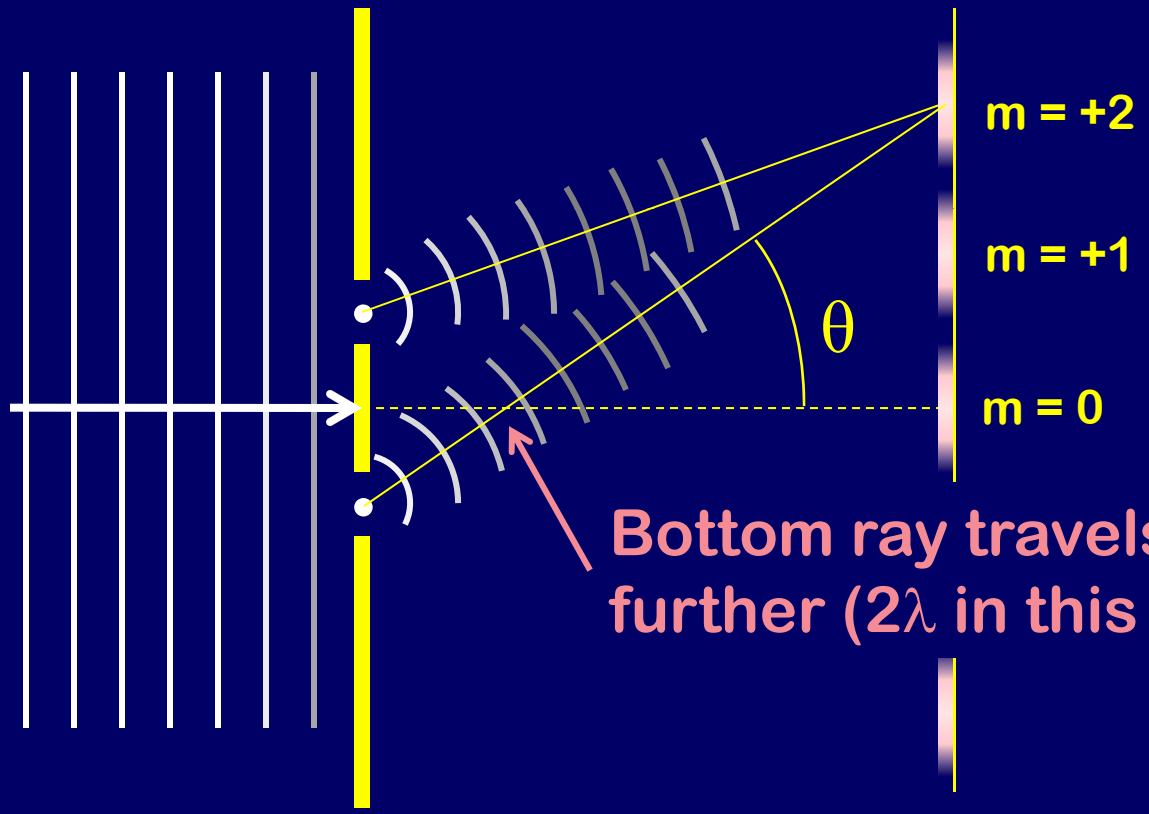
Young's double slit/Huygens

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



Young's double slit: Key idea

Consider two rays traveling at an angle θ:

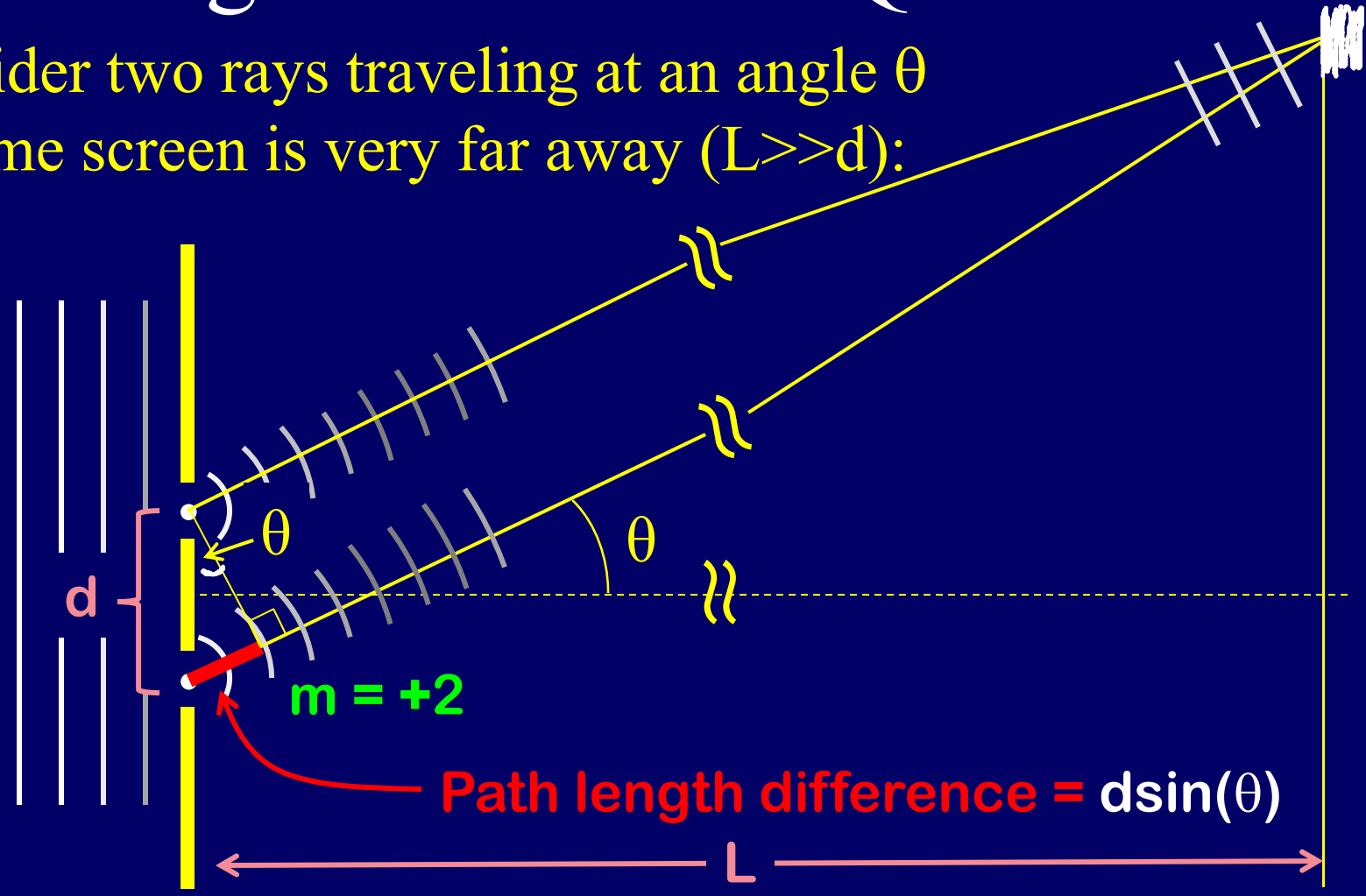


Key for interference is this small extra distance.

Young's double slit: Quantitative

Consider two rays traveling at an angle θ

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



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

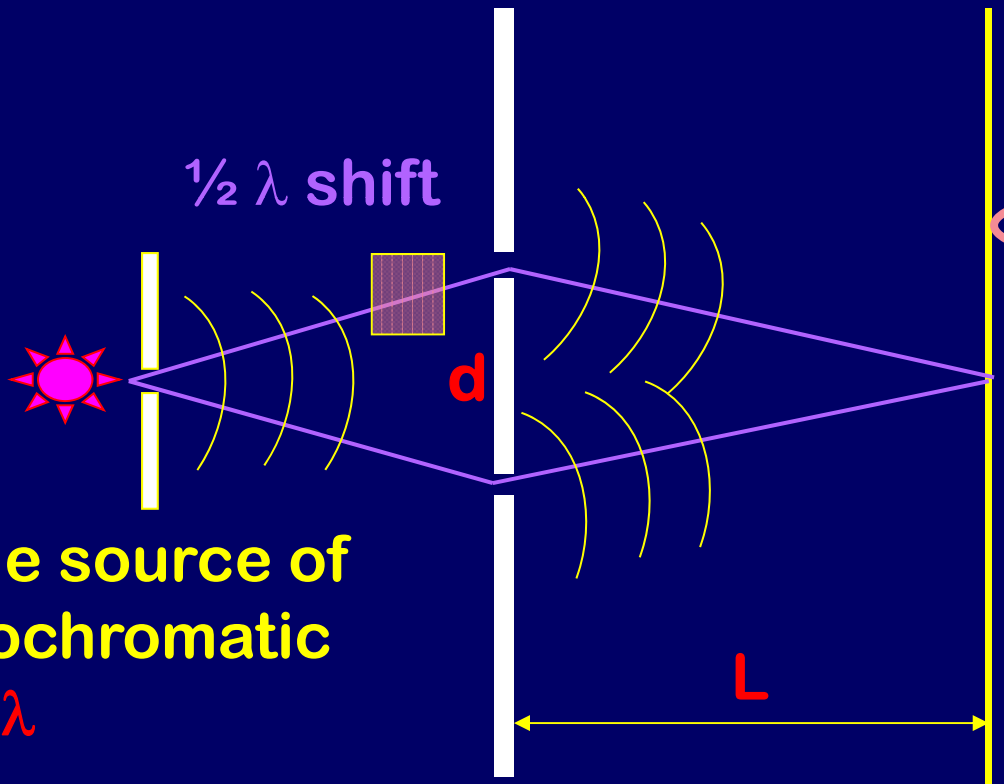
Destructive: $d\sin(\theta) = (m+1/2)\lambda$

where $m = 0, \pm1, \pm2\ldots$

Need $\lambda < d$

ACT/Checkpoint 1.1

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



A. Constructive

B. Destructive

C. Depends on L

Single source of monochromatic light λ

2 slits- separated by d

Screen a distance L from slits

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

See you Wednesday!