Outline

Models of Light: Waves

Office Hours (in course center):

Thursday 5/2 5-6.30pm

Friday 5/10 2-3pm review questions

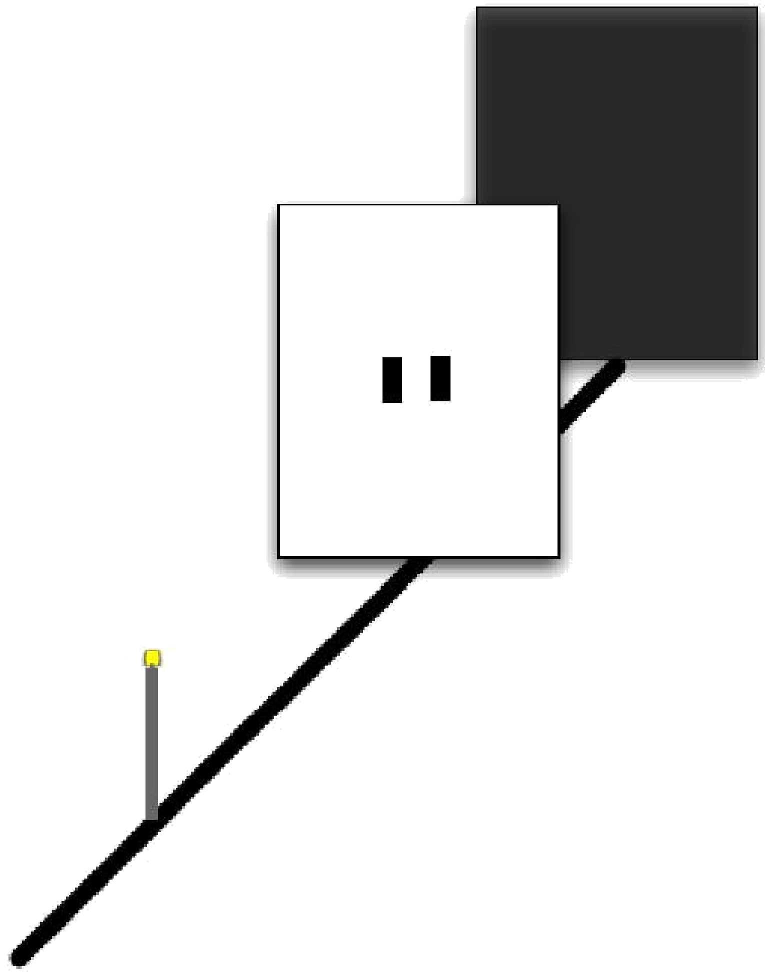
3-4pm office hours

Quiz 10

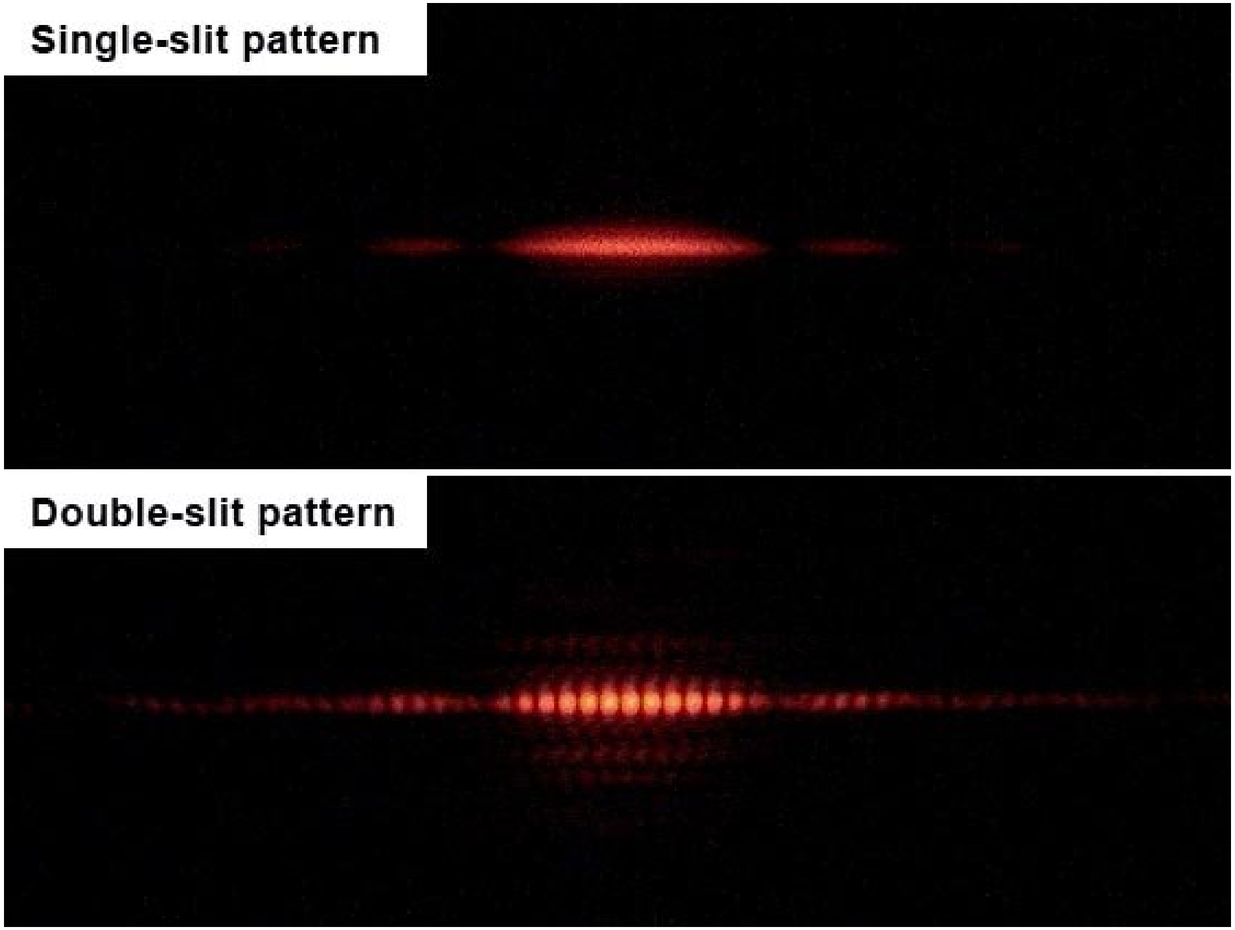
6.2				
Correct	E	D	B	B

We have to 100 micron wide slits. What do we expect from light rays?

1. Two sharp bright spots
2. Two blurry bright spots
3. One wide blurry bright spot
4. One wide sharp bright spot
5. Something else



What a difference a slit makes

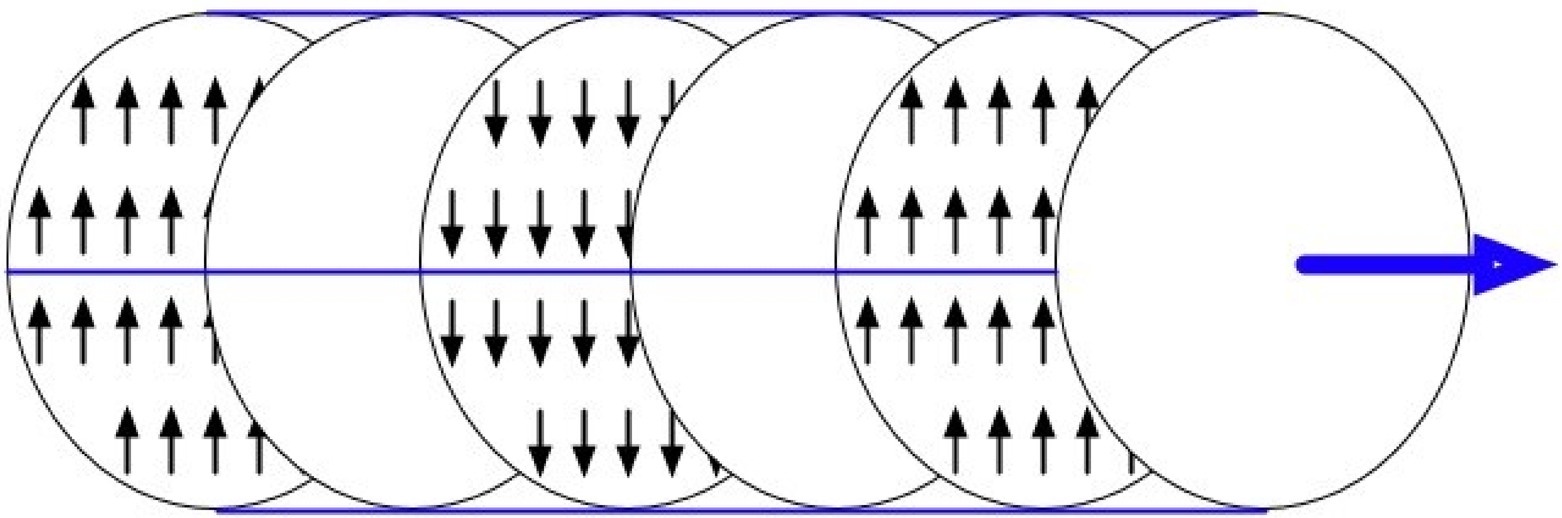


The big deal here is that opening an additional slit makes it *darker* in some places.

No way this happens in either the ray or photon model.

The third model for light: Electromagnetic wave

- Light is an oscillating electromagnetic wave. (Long story)
- A “close-up” of a ray: a plane wave



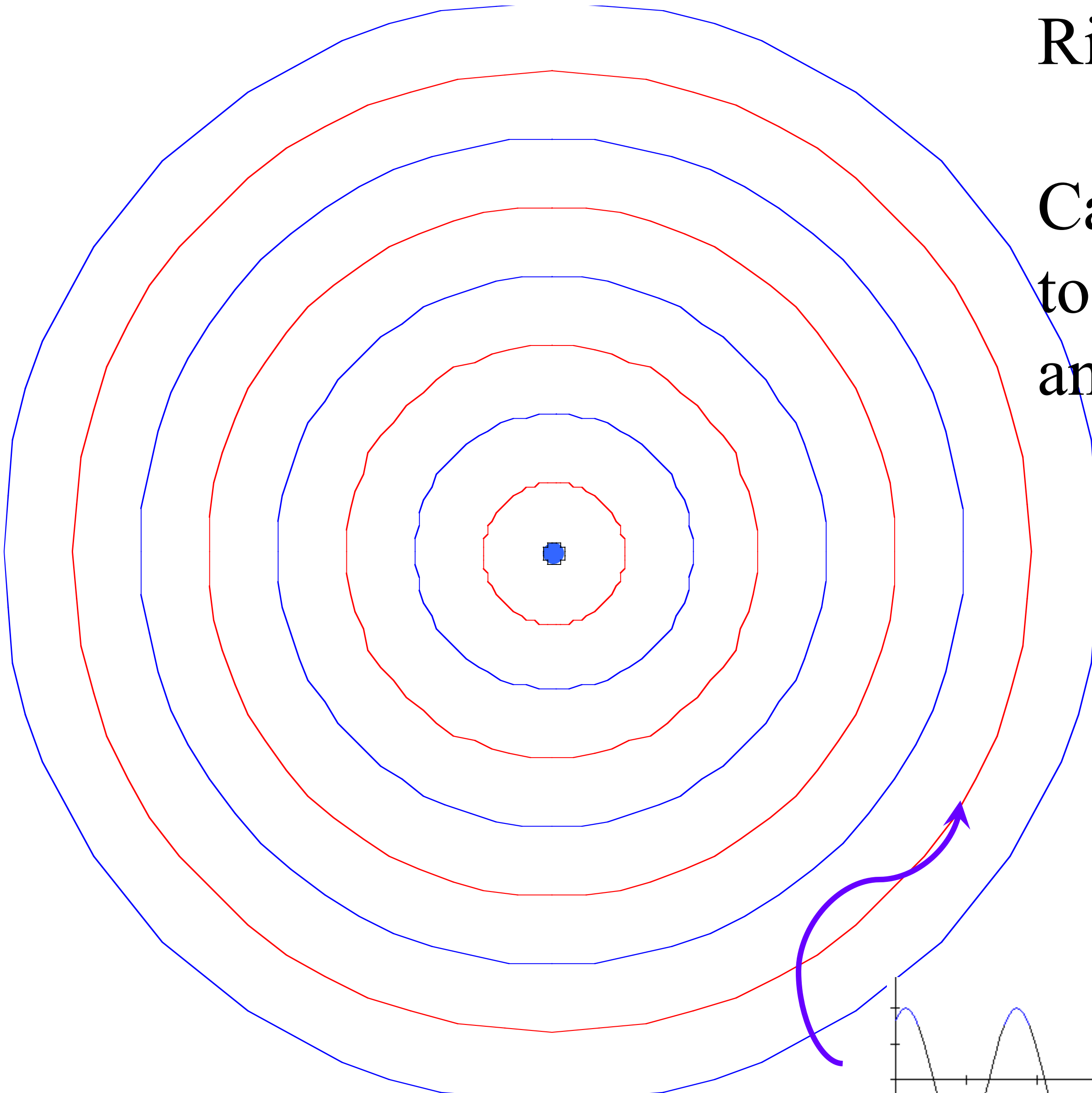
$$\vec{E}(x,y,z,t)=\vec{E}_0 \sin(kx-\omega t)$$

It's hard to picture EM waves in 3D

- Let's build some intuition by working through a simpler example.

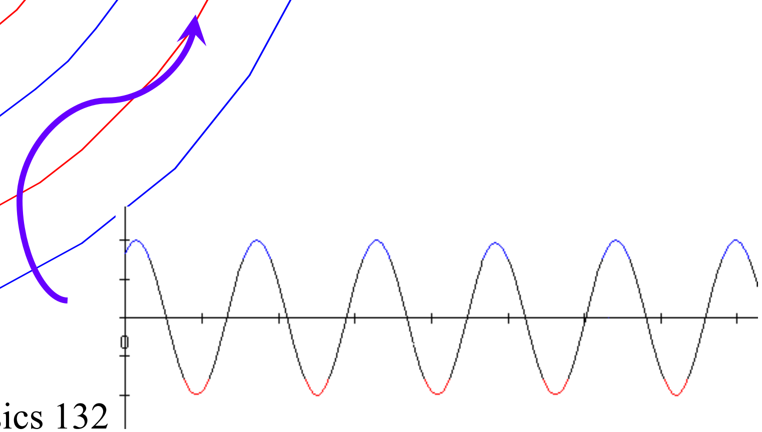
  Waves on the surface of water

  (treating the height of the surface only – that moves up and down – transvers to the wave motion: the actual bits of water move in small circles) http://www.falstad.com/ripple/

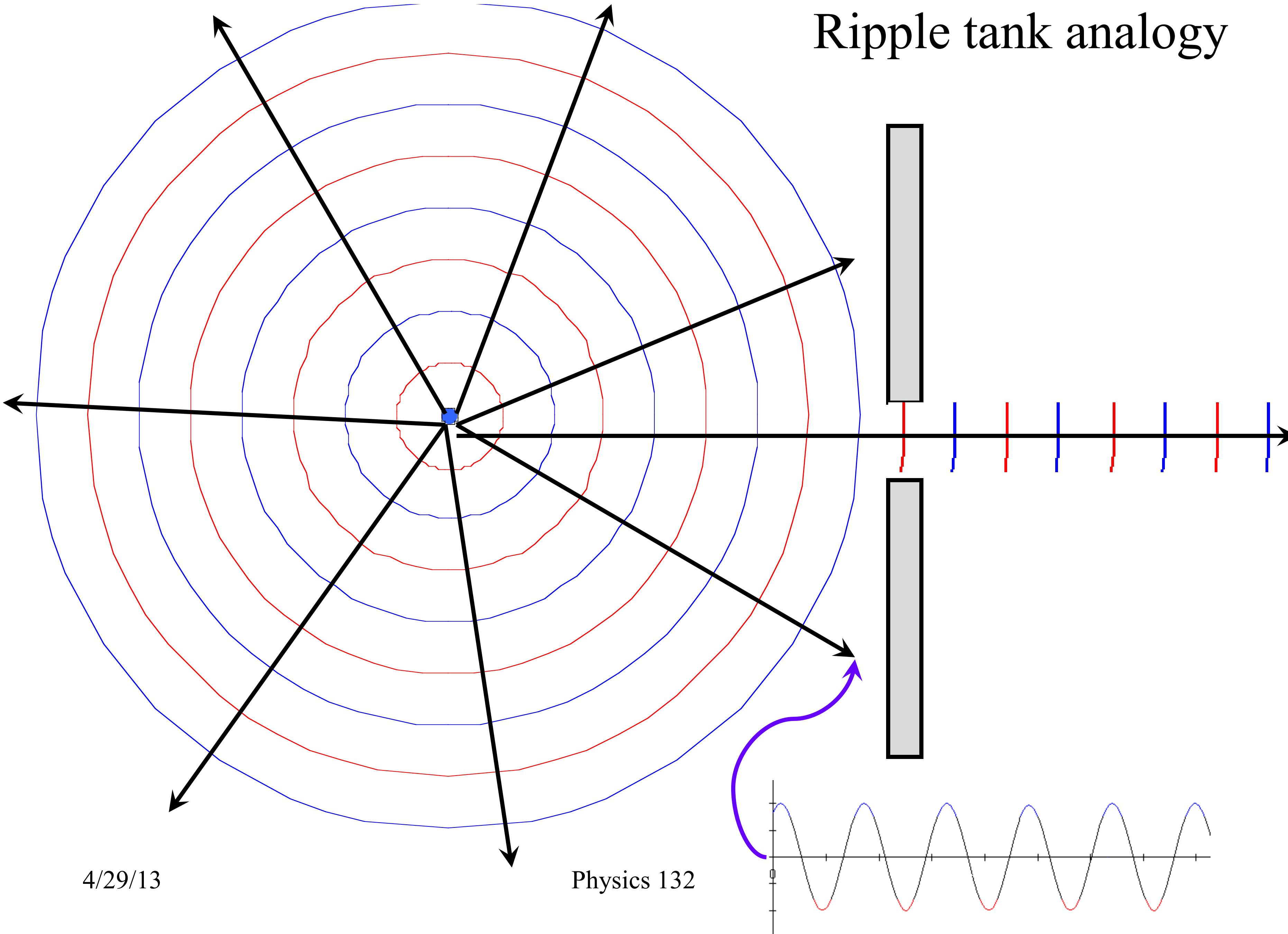


Ripple tank analogy

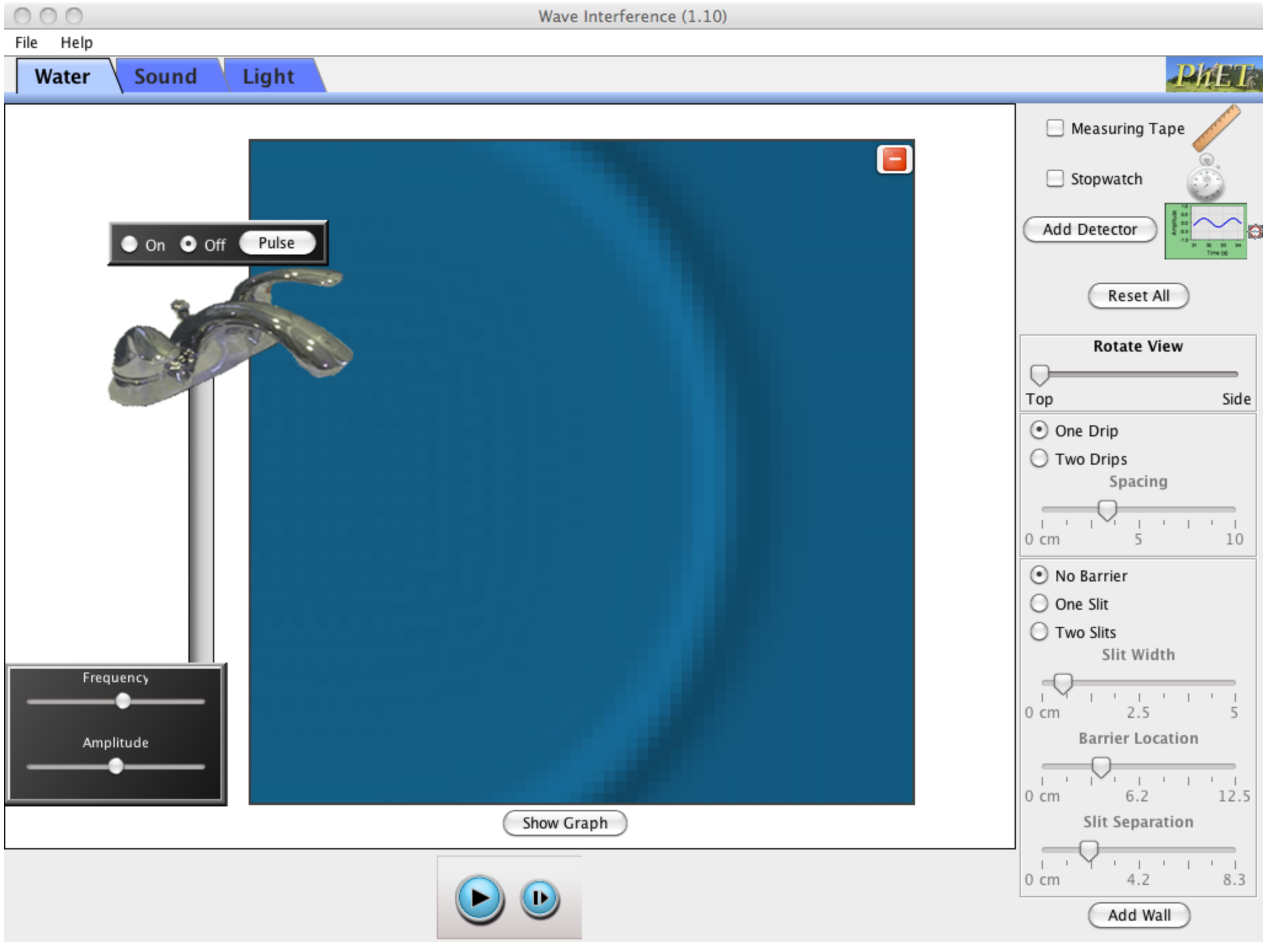
Can two sources lead to both "bright spots" and "dark spots"?



Ripple tank analogy



Explore the PhET sim



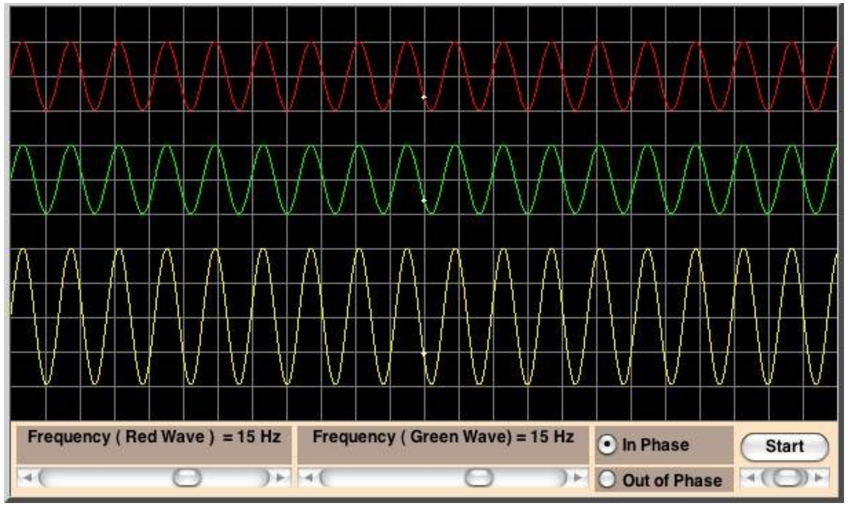
http://phet.colorado.edu/en/simulation/wave-interference

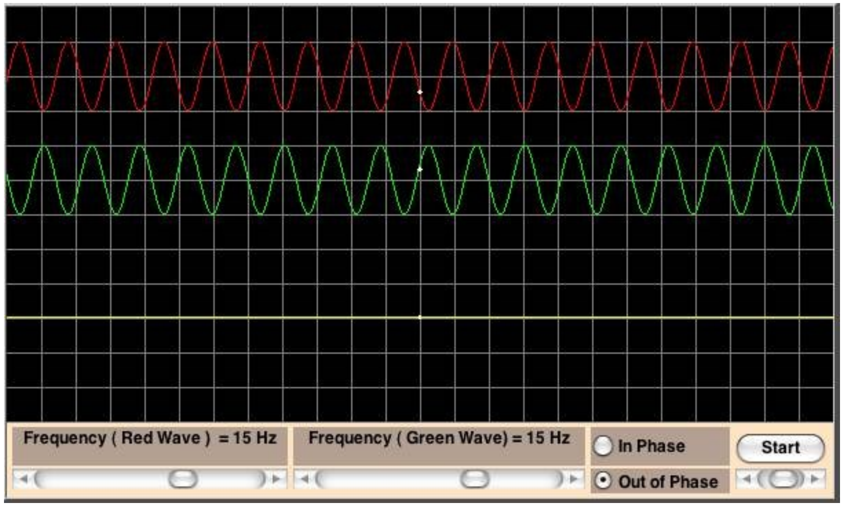
Foothold wave ideas: Huygens' Model

- The critical structure for waves are the lines or surfaces of equal phase: <u>wavefronts</u>.
- Each point on the surface of a wavefront acts as a point source for outgoing spherical waves (wavelets).
- The sum of the wavelets produces a new wavefront.
- The waves are <u>slower</u> in a denser medium.
- We can even make rays – sort of.

Beats

- When we add two waves of the same frequency,
  - if their phases differ by 0, 2π, 4π, …. they add (constructive interference).
  - if their phases differ by π, 3π, 5π, …. they cancel





Phase difference and path difference

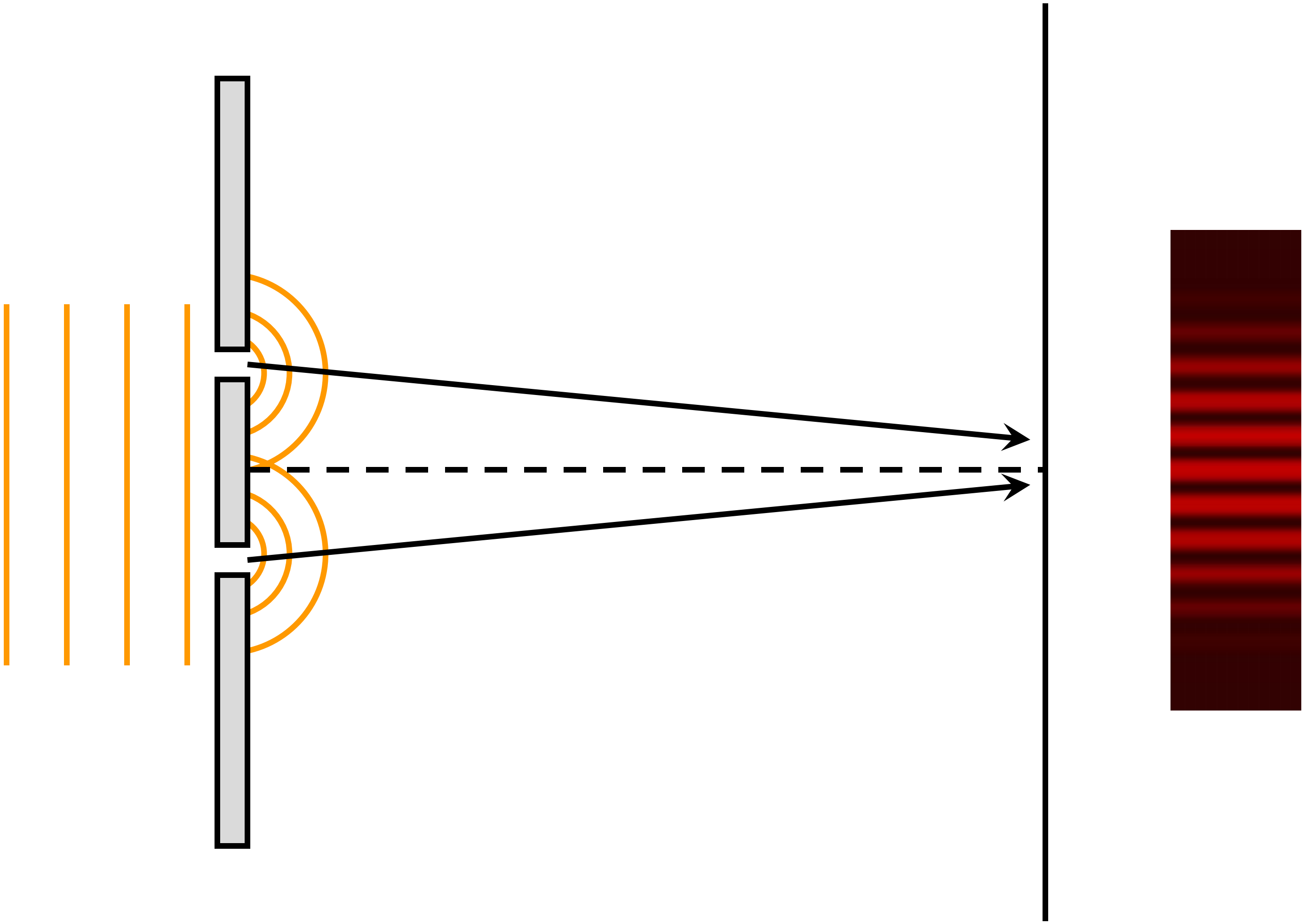
- Our two waves from different sources have a phase difference, $\phi_1 - \phi_2$ because we are different distances from the two sources.

  $$y = A\sin(kr_1 - \omega t) + A\sin(kr_2 - \omega t)$$
  $$y = A\sin(\phi_1 - \omega t) + A\sin(\phi_2 - \omega t)$$

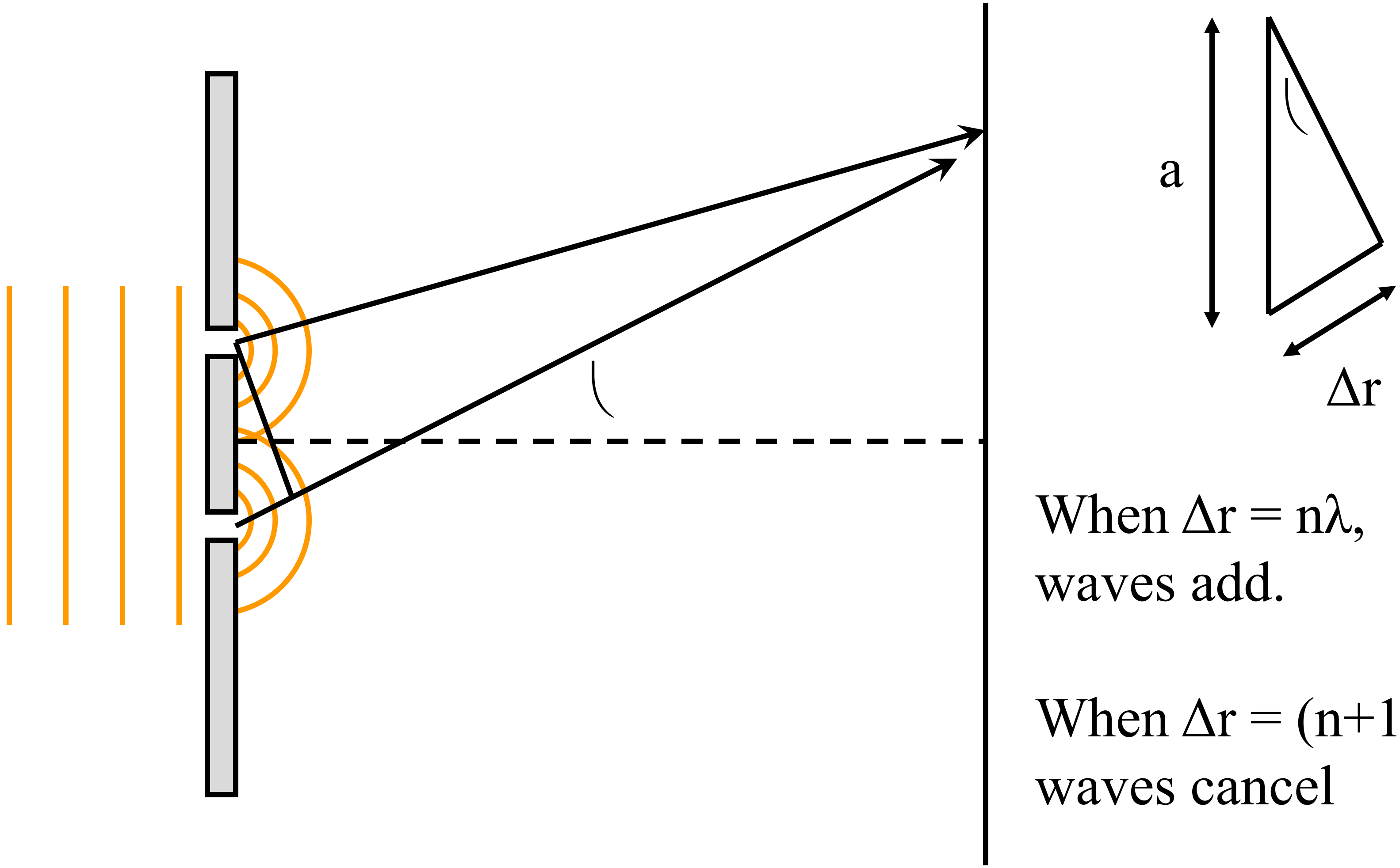
- The phase difference depends on the path difference:

$$\phi_1 - \phi_2 = kr_1 - kr_2 = k\left(r_1 - r_2\right) = k\Delta r = 2\pi\frac{\Delta r}{\lambda}$$

A First Test: Interference

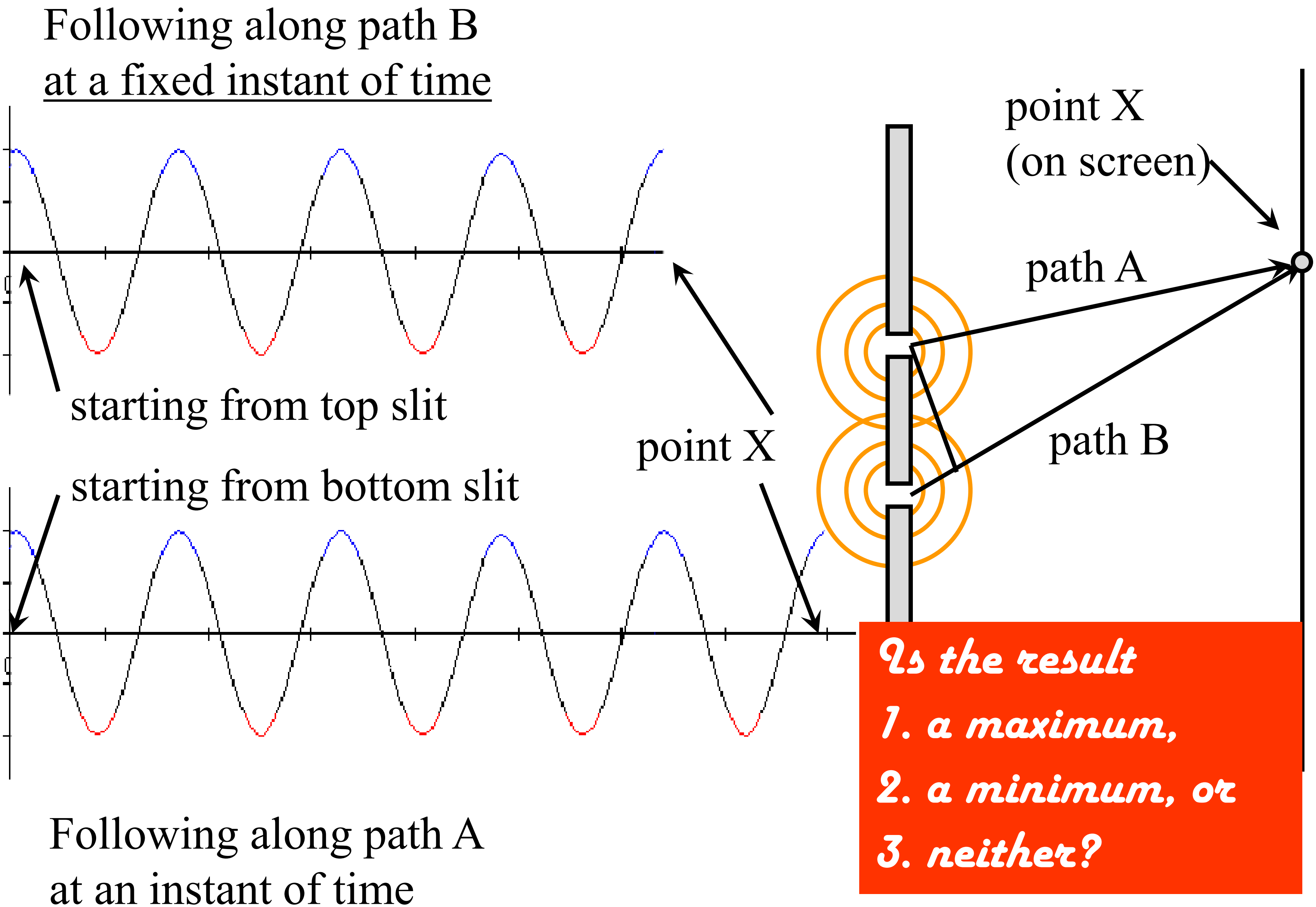


A First Test: Interference

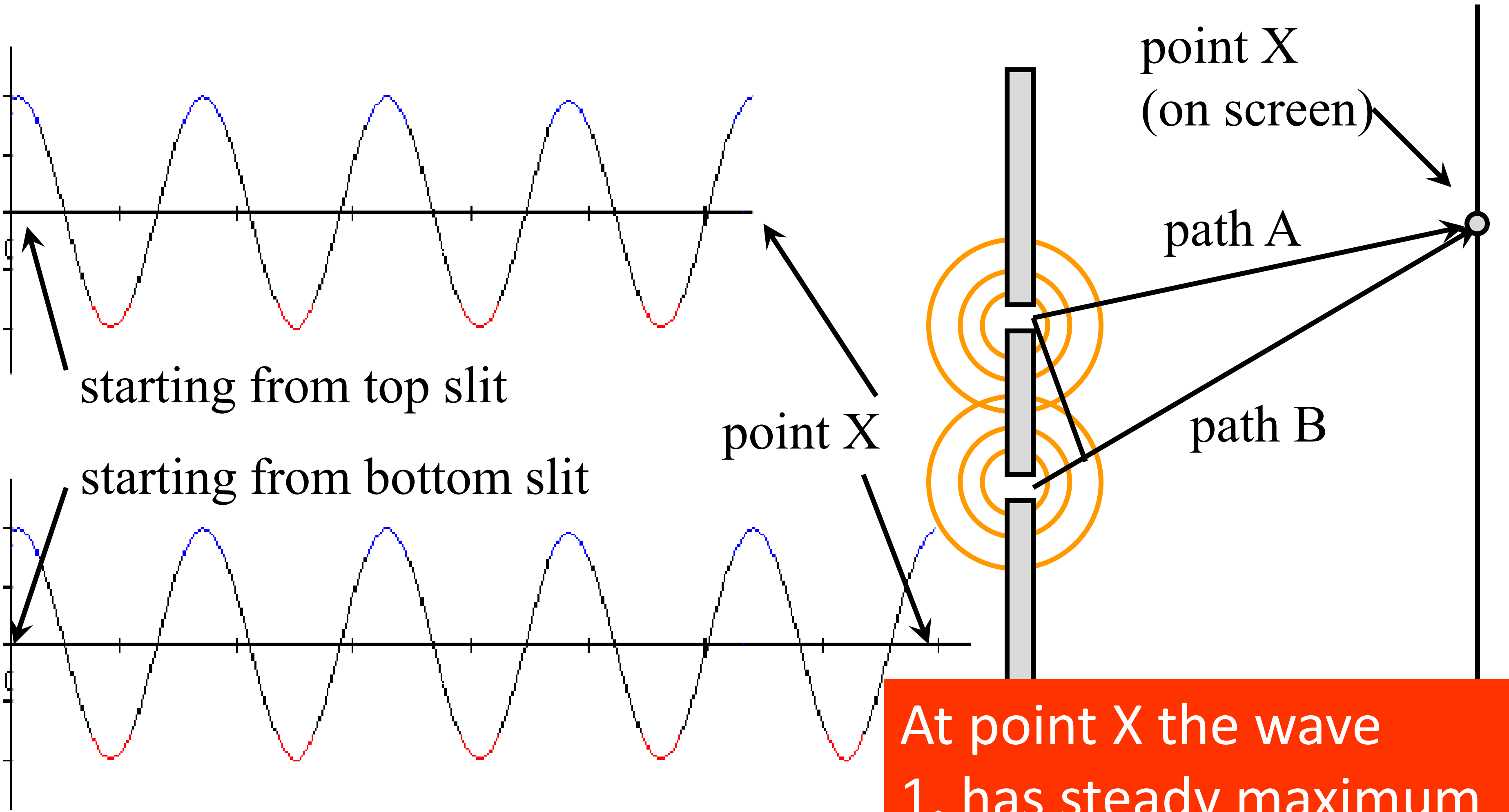


When $\Delta r = n\lambda$,
waves add.

When $\Delta r = (n+1/2)\lambda$,
waves cancel


Following along path B
at a fixed instant of time
starting from top slit
point X
(on screen)
path A
path B
point X
starting from bottom slit
Following along path A
at an instant of time
Is the result
1. a maximum,
2. a minimum, or
3. neither?

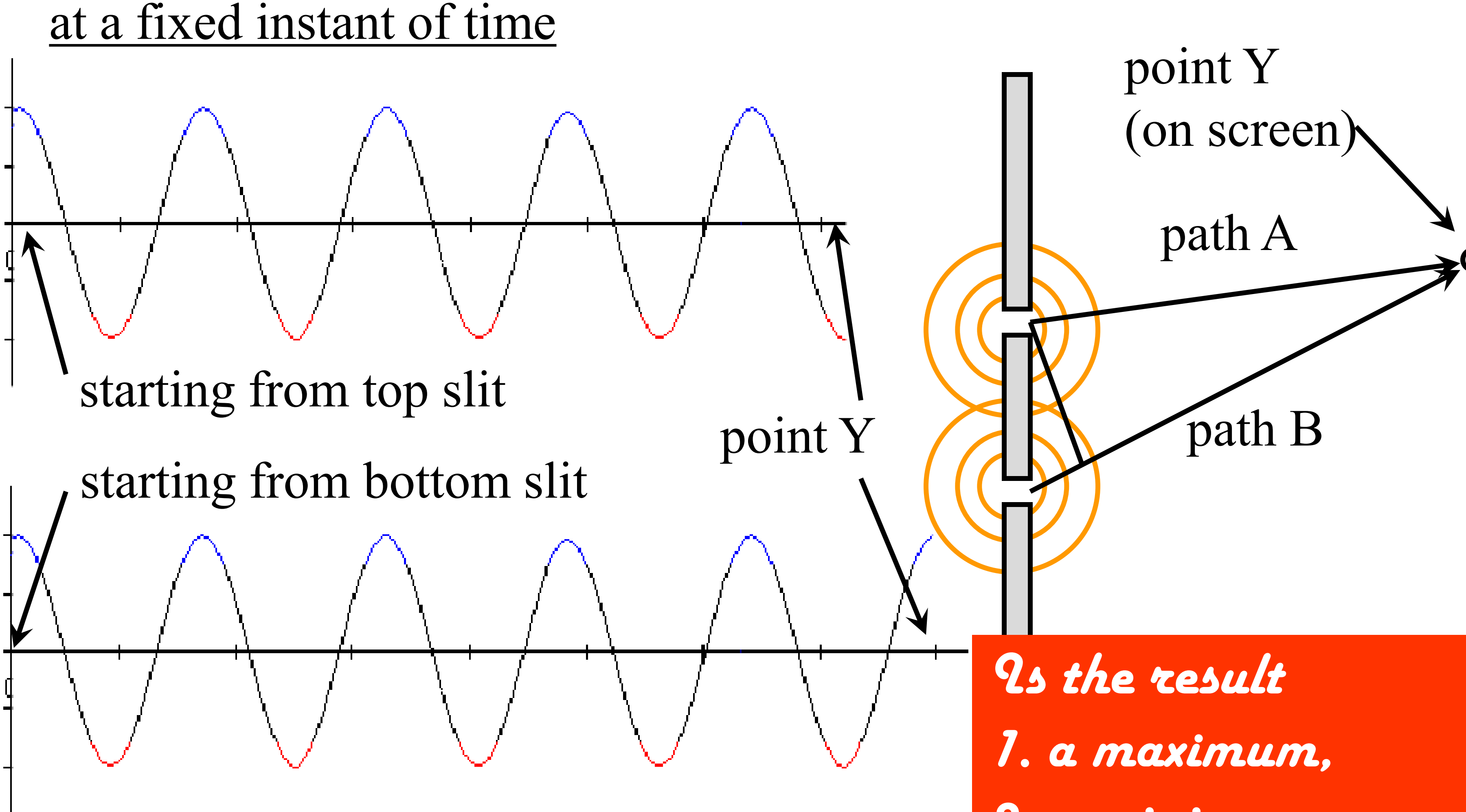
AT A LATER TIME after the time shown below the waves have traveled



Following along path A
at an instant of time

At point X the wave
1. has steady maximum
2. Oscillates
3. neither?

Following along path B
<u>at a fixed instant of time</u>



Is the result

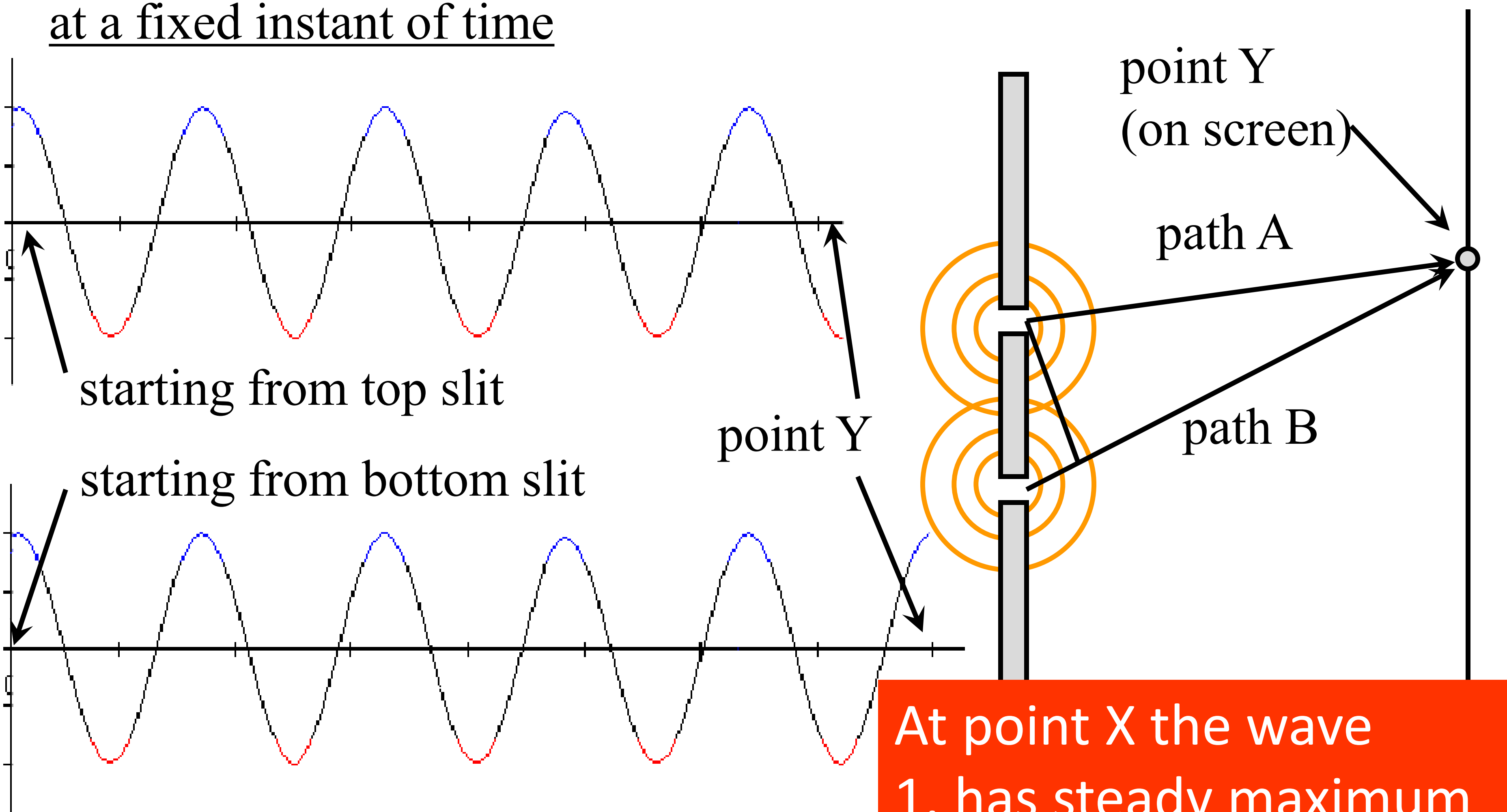
1. a maximum,

2. a minimum, or

3. neither?

Following along path A
at an instant of time

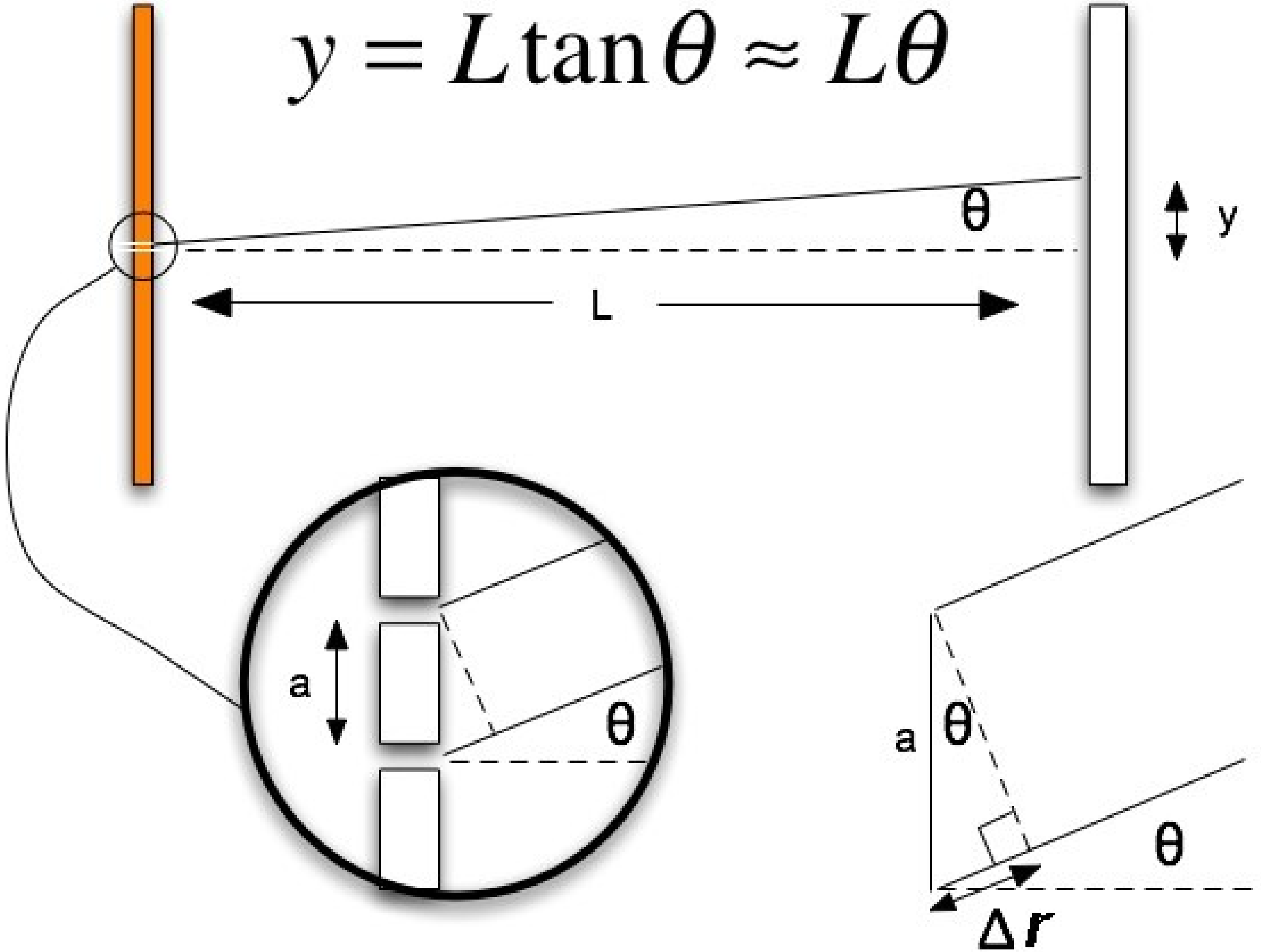
Following along path B
at a fixed instant of time



Following along path A
at an instant of time

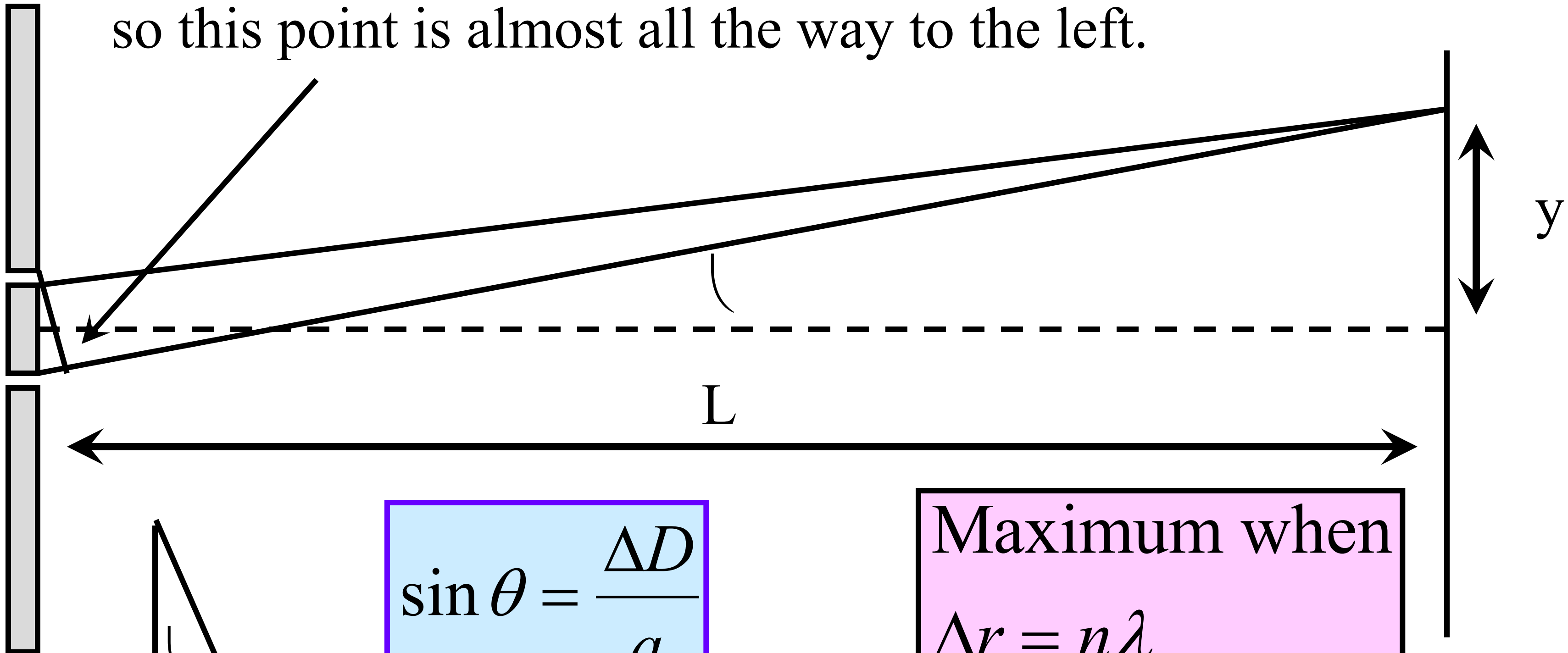
At point X the wave
1. has steady maximum
2. Oscillates
3. neither?

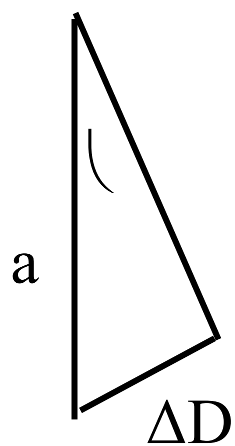
$$y = L\tan\theta \approx L\theta$$



$$\Delta r = a\sin\theta \approx a\theta$$

Slits are really much, much closer than shown so this point is almost all the way to the left.





$$\sin\theta = \frac{\Delta D}{a}$$

$$\tan\theta = \frac{y}{L}$$

Maximum when

$$\Delta r = n\lambda$$

Minimum when

$$\Delta r = (n + \tfrac{1}{2})\lambda$$

For small angles,
$\sin \theta \sim \theta$, $\tan \theta \sim \theta$ $\Rightarrow \quad \frac{\Delta r}{a} = \frac{y}{L} \quad \Rightarrow \quad y = \Delta r\left(\frac{L}{a}\right)$