Double-slit Diffraction and Interference

Back to Waves

- We've recently explored geometric aspects of light: bundles of waves behave like geometric rays that reflect and refract. (Lenses, mirrors)
- Some light phenomena cannot be explained with geometric optics:
  - Interference
  - Diffraction
  - Polarization

Superposition Principle

- A very general concept in physics.
- Main idea: two or more of the same quantity acting at the same position at the same time add to give a quantity of the same type
- Examples:
  - Superposition of vectors (forces, fields):

$$\vec{F}_1 + \vec{F}_2 = \vec{F}_{net}, \qquad \vec{E}_1 + \vec{E}_2 = \vec{E}_{net}$$

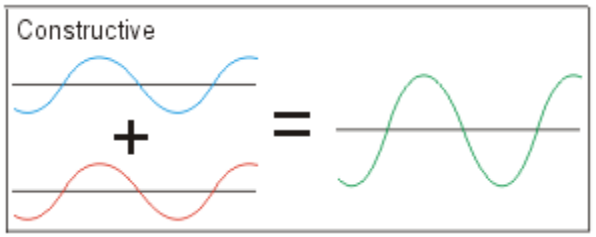
  - Waves as we will discuss today.
- Recommended link (several relevant simulations):

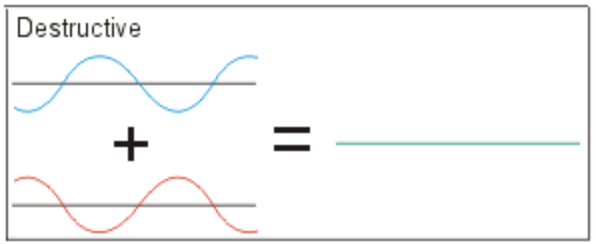
http://www.cabrillo.edu/~jmccullough/Applets/Applets_by_Topic/Superposition_Interference.html

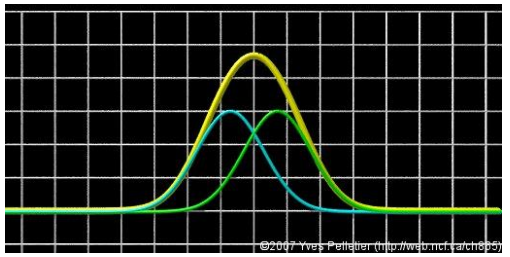
Constructive and Destructive Interference

- **Interference** of waves is the phenomenon that results from the superposition of waves.
- If two waves interfere so that both are in phase (no offsets), they reinforce one another; we call this **constructive interference**
- If the two waves are out of phase (they have an offset), the result is **destructive interference**
- It is possible to have completely constructive, completely destructive or something in between.
- With many waves interfering a pattern forms that can be captured on a screen called **interference pattern**
- Simulation:

  http://phschool.com/atschool/phsciexp/active_art/wave_interference/wave_interference.swf



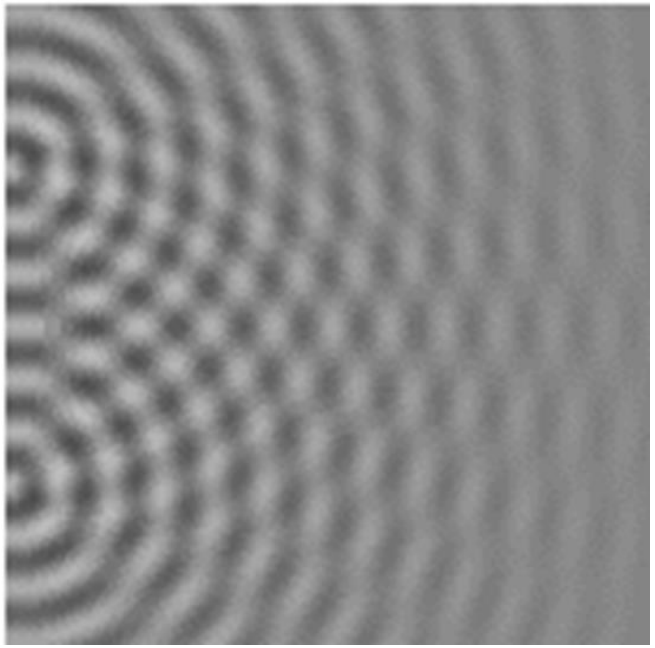




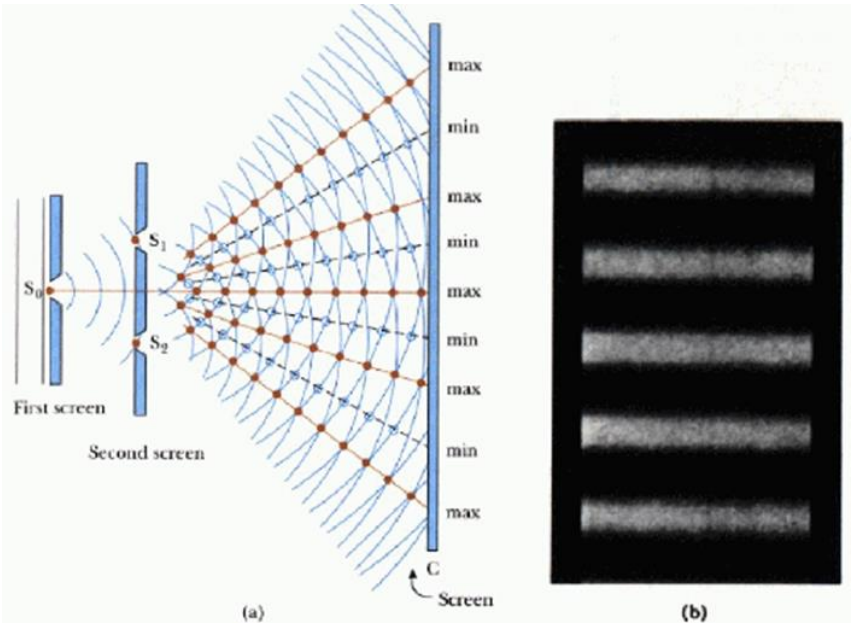
Interference from Two Slits (Coherent Point Sources)

http://www.youtube.com/watch?v=dNx70orCPnA

Water waves



Light waves



Path length difference: determines whether there is constructive or destructive interference at a given point

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

Quickuiz

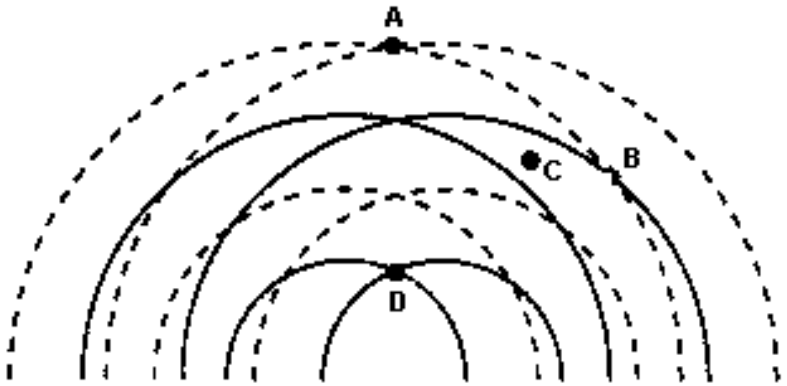
Two wave sources operating in phase in the same medium produce the circular wave patterns shown in the diagram. The solid lines represent wave crests and the dashed lines represent wave troughs. Which point is at a position of maximum destructive interference?

A.

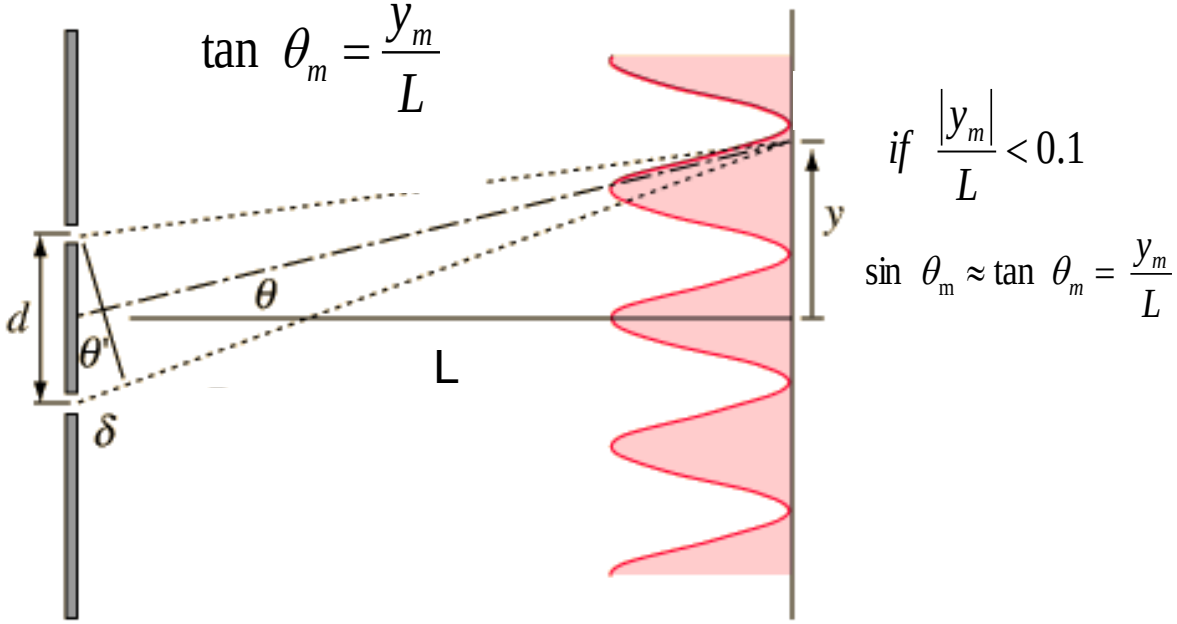
B.

C.

D.



Analyzing two-slit interference mathematically



- Condition for minimum: $d \sin\theta_m = \left(m - \frac{1}{2}\right)\lambda$

Simulation: http://www.walter-fendt.de/ph14e/doubleslit.htm

Summary for the Young Double-Slit Experiment

- **Diffraction** occurs as light passes through **slits**
- Diffracted light **interferes** creating a **diffraction pattern** on a screen
- The pattern has **bright** and **dark** regions called **fringes**
- The **bright fringes** correspond to **constructive interference** where the path difference is an **integer multiple of** λ:

$$d \sin \theta_m = m\lambda, \qquad m = 1,2,3, \ldots$$

- The **dark fringes** correspond to **destructive interference** where the path difference is a **half-integer multiple** of λ:

$$d \sin \theta_m = \left(m - \frac{1}{2}\right)\lambda, \qquad m = 1,2,3, \ldots$$

Quickuiz

If the red light source in the simulation demonstrating double-slit diffraction is replaced by a blue light source, the pattern on the screen _____ .

A. will not change, except it will be colored blue

B. will show fewer maxima and minima (which are now blue)

C. will show more maxima and minima (which are now blue)

D. Sorry, I'm clueless!

$$d \sin \theta_m = \left(m - \frac{1}{2}\right)\lambda$$