March 11, 2011 Physics 122 Prof. E. F. Redish

- **Theme Music:** George Winston
  Ocean Waves
- **Cartoon:** Bill Watterson
  Calvin & Hobbes

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Outline

- Finish ILD 2
- A challenge to our foothold ideas about light
- Light as waves
  - Huygens' Principle
  - Interference
  - Connecting to the ray model

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What was going on in this experiment?

- When in lab you put light through a thin pair of slits, you got a pattern different than we would expect from our light and shadow ray-model analysis.

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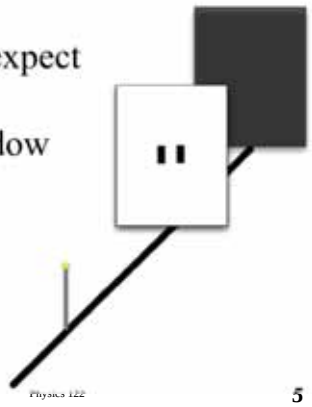
What do we expect from our light and shadow analysis?

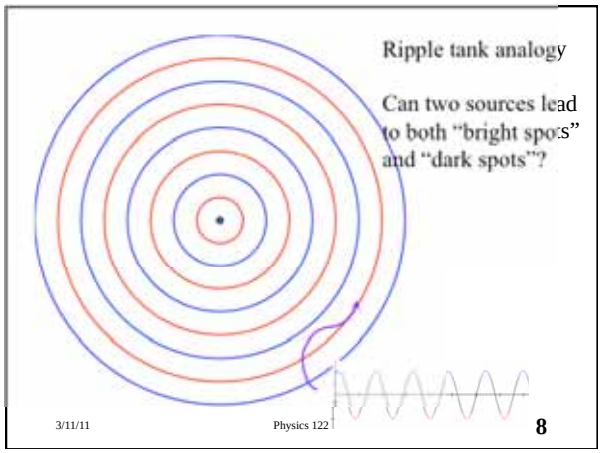


Huh?

- Can we explain this result in the ray model?
  - or do we need something different?
- The really strange part is that by opening another source, at some places we wind up getting less light!
- Remember our early definition of a "foothold idea".

The Wave Model of Light: Pros

- About the same time as Newton, a Dutch physicist, Christiaan Huygens proposed that light was a wave – a kind of oscillation in "the ether that fills empty space." (Whatever that means.)
- An oscillation can help us explain the "cancellation" that happens when we open another source.
  - Two out of phase oscillations satisfying a "superposition principle" can cancel at some places.


Ripple tank analogy
Can two sources lead to both "bright spots" and "dark spots"?
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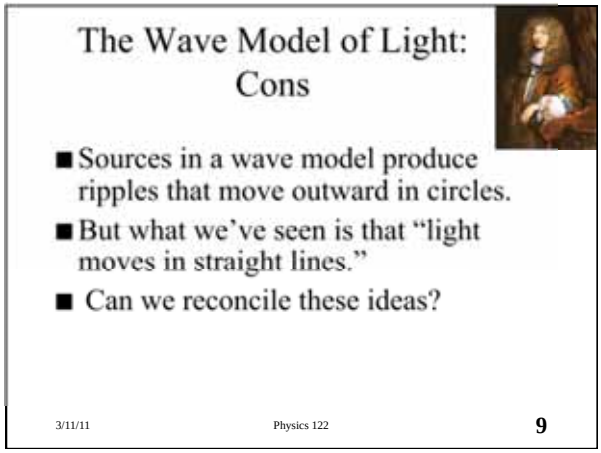
The Wave Model of Light: Cons
Sources in a wave model produce ripples that move outward in circles.
But what we've seen is that "light moves in straight lines."
Can we reconcile these ideas?
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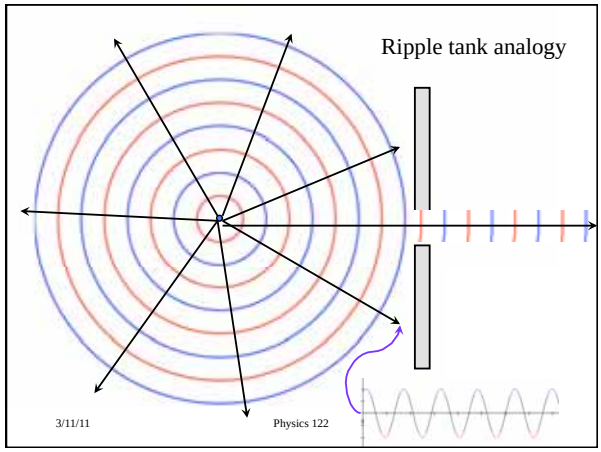
Ripple tank analogy
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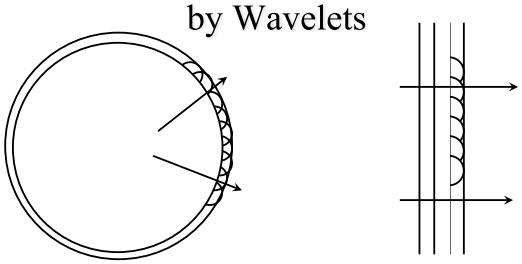
Waves to Rays

- We can isolate a small piece of a wave by passing it through a hole in a screen and treat it like a ray.
- We can consider the rays as going perpendicular to the wave surfaces of constant height.
- If the wiggles in the waves are small and fast enough, we can ignore the oscillations.

Huygens' Principle

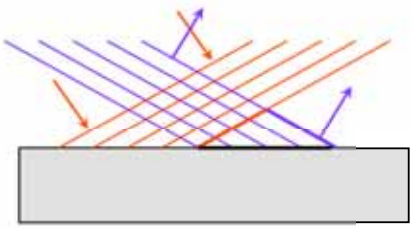
- Christian Huygens (a Dutch contemporary of Newton) proposed a way of thinking about how waves propagate.
- The critical structure for waves are the surfaces of equal amplitude: wavefronts.
- Huygens suggested:
  Each point on the surface of a wavefront acts as a point source for outgoing spherical waves (wavelets). The sum of the wavelets produces a new wavefront.

Propagation of Waves by Wavelets

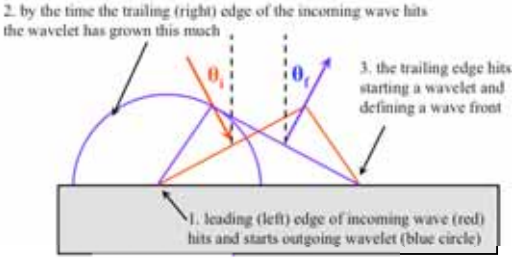


The wavelet model implies that a plane wave will travel in a straight line.

Reflection from a Mirror in Huygens' Wavelet Model



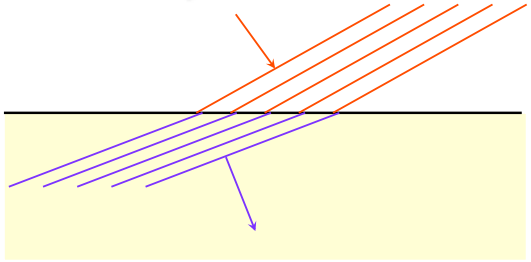
http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=16

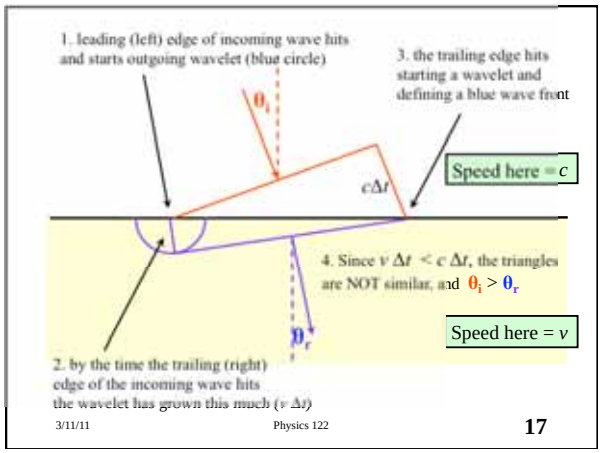


4. Since the red and blue triangles are similar, $\theta_i = \theta_f$

The wavelet model implies that a plane wave will reflect off a mirror according to the rule:
angle of incidence = angle of reflection.

Refraction of Waves by Wavelets




1. leading (left) edge of incoming wave hits and starts outgoing wavelet (blue circle)
3. the trailing edge hits starting a wavelet and defining a blue wave front
Speed here = c
cΔt
4. Since v Δt < c Δt, the triangles are NOT similar, and θi > θr
Speed here = v
2. by the time the trailing (right) edge of the incoming wave hits the wavelet has grown this much (v Δt)
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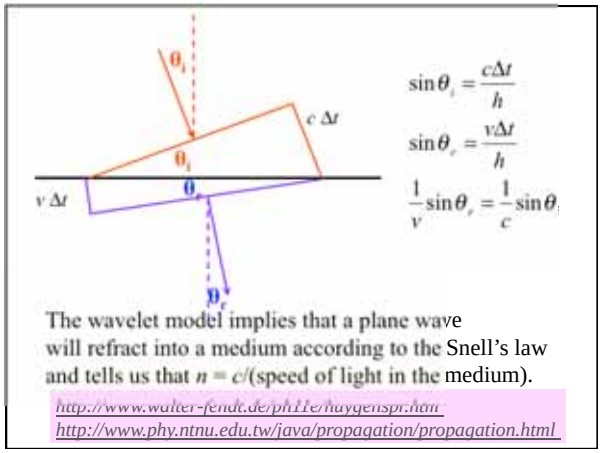
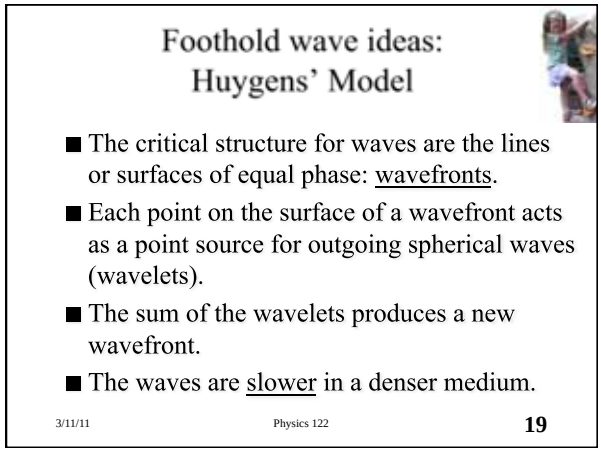

c Δt
v Δt
$\sin\theta_i = \frac{c\Delta t}{h}$
$\sin\theta_r = \frac{v\Delta t}{h}$
$\frac{1}{v}\sin\theta_r = \frac{1}{c}\sin\theta_i$
The wavelet model implies that a plane wave will refract into a medium according to the Snell's law and tells us that n = c/(speed of light in the medium).
http://www.walter-fendt.de/ph11e/huygenspr.htm
http://www.phy.ntnu.edu.tw/java/propagation/propagation.html


Foothold wave ideas:
Huygens' Model
■ The critical structure for waves are the lines or surfaces of equal phase: wavefronts.
■ 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 slower in a denser medium.
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