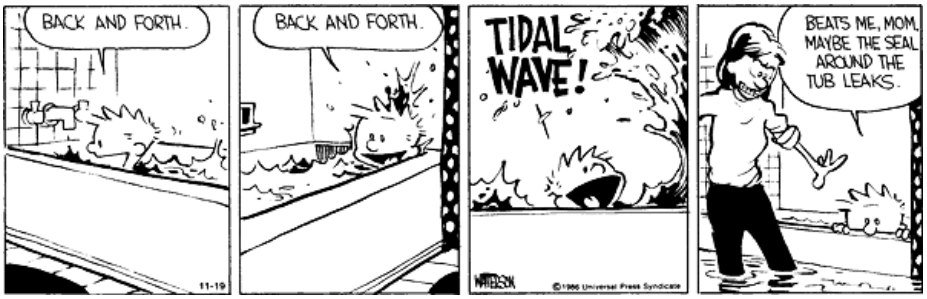
April 29, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:** **Pat Green**
  Wave on Wave
- **Cartoon:** **Bill Watterson**
  Calvin & Hobbes

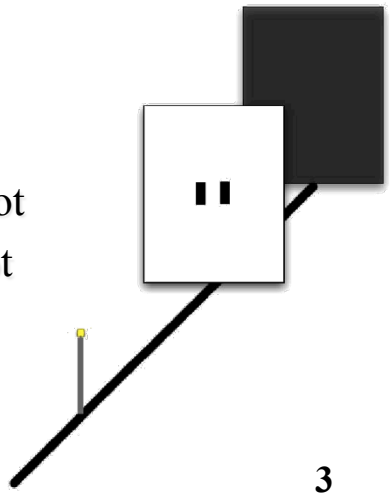


Reading question

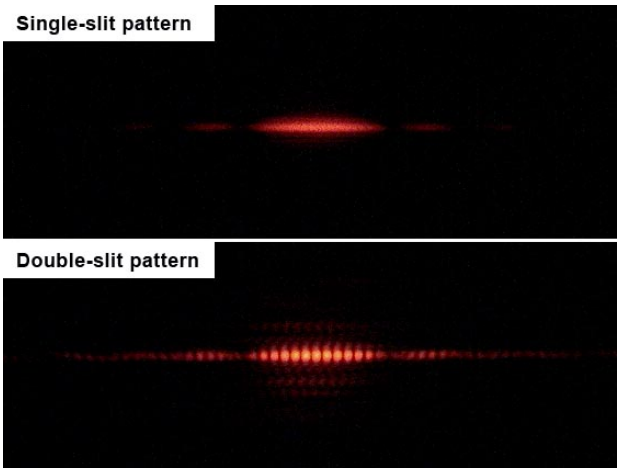
- At what point can we stop adding models and admit that nobody actually understands light and only think they do?

What do we expect from our light and shadow analysis?

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 Newton's particle model.

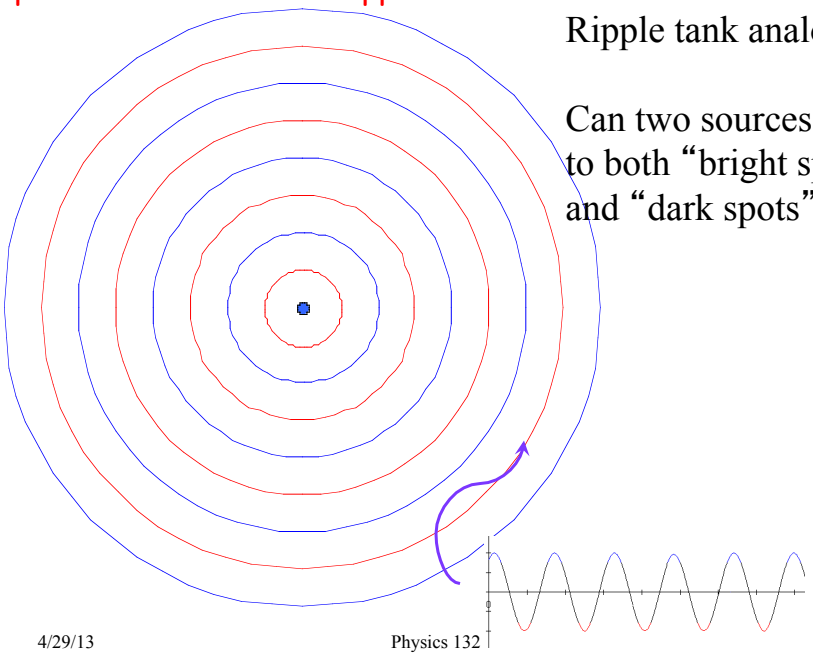
It's hard to picture EM waves in 3D

- 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 – transverse to the wave motion: the actual bits of water move in small circles)

http://www.falstad.com/ripple/

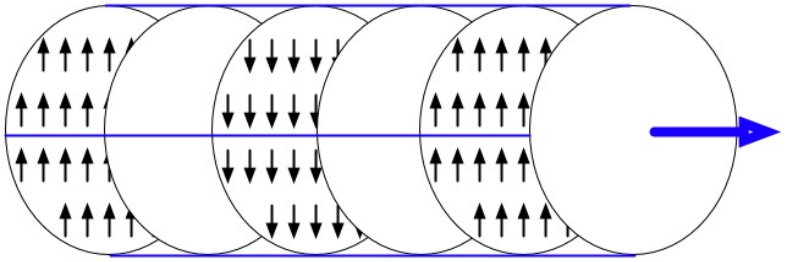


Ripple tank analogy

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

What is light?...Really?

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



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

Reading questions

- I was really confused about the polarization of waves. How do we analyze this concept for our purposes or are mainly just dealing with linearly polarized waves? How exactly are circularly or elliptically polarized waves depicted graphically as well?
- I don't understand the concept that since the EM wave has different polarizations, that means it can carry more information than just intensity. What information does it carry, color and position?

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.
- We can even make rays – sort of.

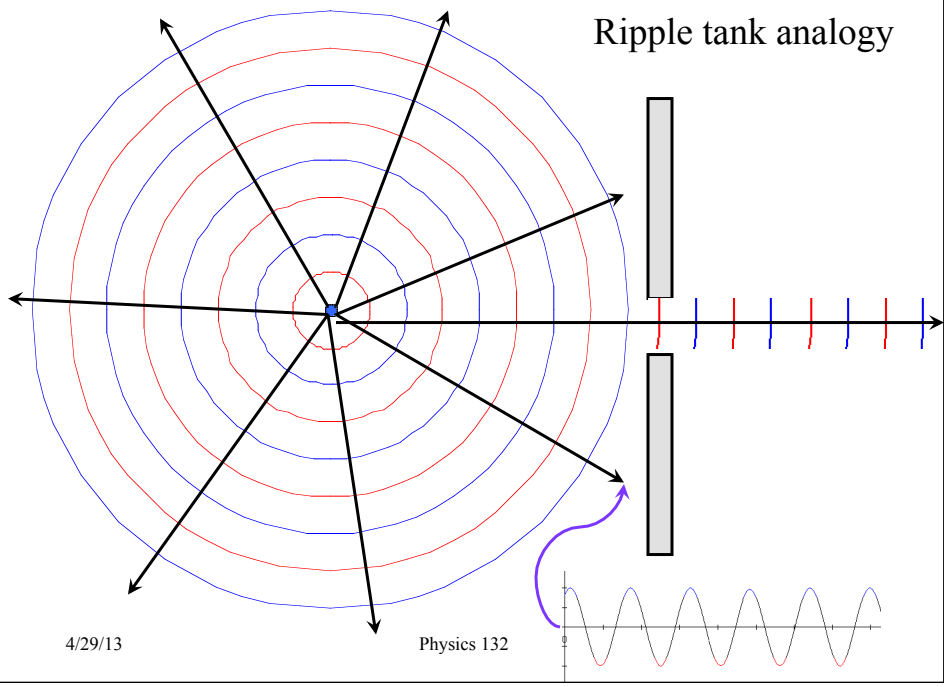
Reading questions

- I don't understand how two sources of light can cancel each other out. How can light be both positive and negative?
- How can light be both positive and negative? Do the light waves cancel each other out at the certain points like the waves that are completely out of sync?
- How can having more sources of light cause different points to cancel out? Wouldn't the points be twice as bright instead? Does this happen because the light is considered both positive and negative?

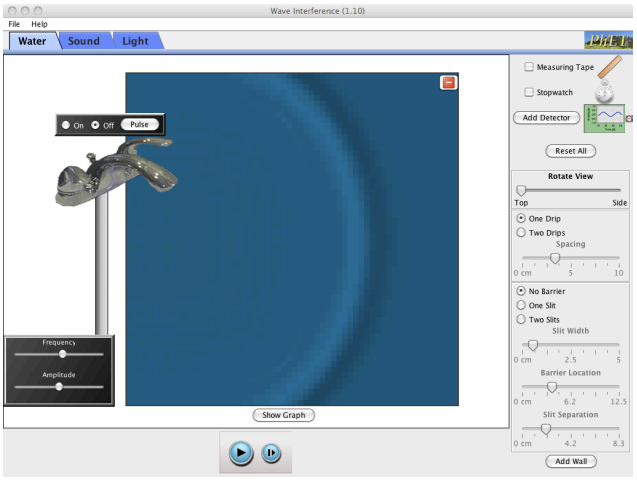
Reading Questions

- I was extremely confused by the idea of wavelets. Are wavelets just the secondary waves that follow the original wave due to the force from the original wave? I am not exactly how these are relevant to us if there is a driver causing an oscillation? I think overall I am just confused as to what a wavelet actually is, and how we can determine the new wavefronts created from existing wavelets?
- When talking about wavelets it says that their sums create new wavefronts, so is each wavelet technically a wavelet in one sense because it is a result of the wavefront prior to it and also a wavefront because it will create new wavelets?

Ripple tank analogy



Explore the PhET sim



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

The math

- Outgoing pulse:

$$y = \frac{f(r - v_0 t)}{\sqrt{r}} \quad \text{(in 2D)}$$

$$y = \frac{f(r - v_0 t)}{r} \quad \text{(in 3D)}$$

These factors reduce the amplitude slightly as the waves go out to conserve total energy (prop. to square of y).

- Outgoing sinusoidal:

$$y = \frac{A\sin(kr - \omega t)}{\sqrt{r}} \quad \text{(in 2D)}$$

$$y = \frac{A\sin(kr - \omega t)}{r} \quad \text{(in 3D)}$$

We will tend to ignore them since the sin factors vary much more.

Superposition from two sources

- If we are at a particular point in space and two traveling waves, $y = A\sin(kr - \omega t)$, reach us coming from different starting points, we are at different "r" values for the two waves.
- The result looks like the sum of two waves with different phases:

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