

The nature of light and wave optics

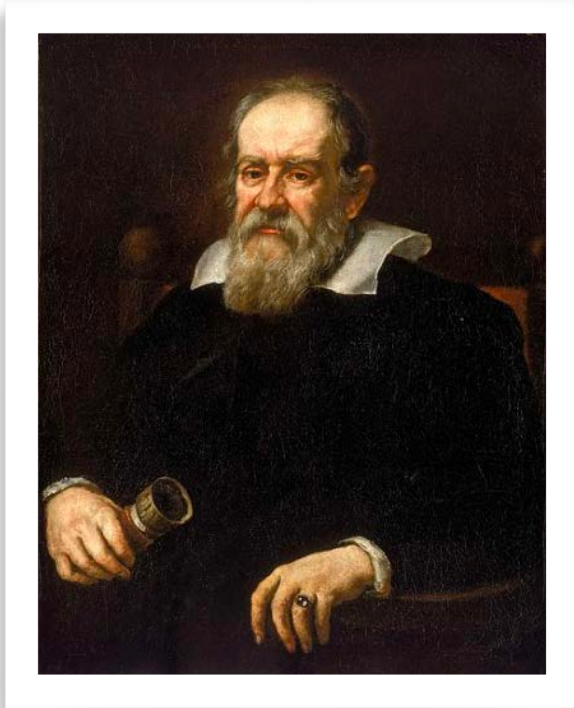
- How to measure the speed of light
- Ray optics and wave optics
- Huygens's principle
- Young's double-slit experiment
- Analysis model: waves in interference
- Intensity distribution of the double-slit interference pattern
- Change of phase due to reflection
- Interference in thin films



Phat Srimanobhas (phat.s@cern.ch)

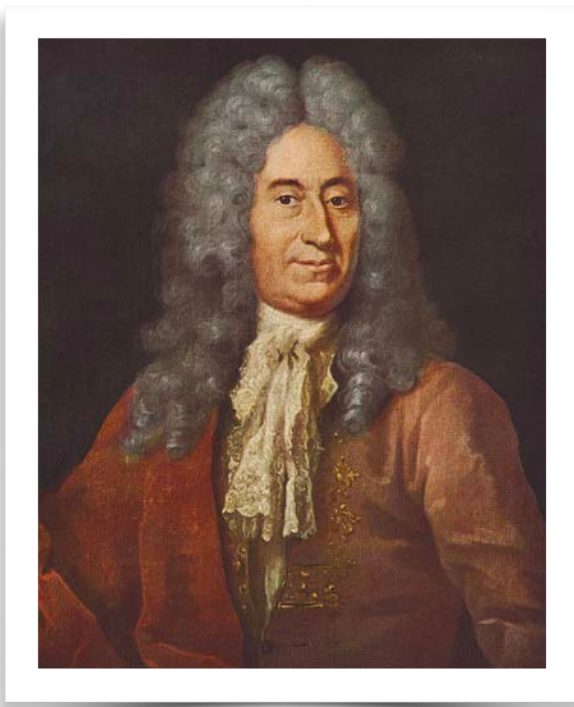
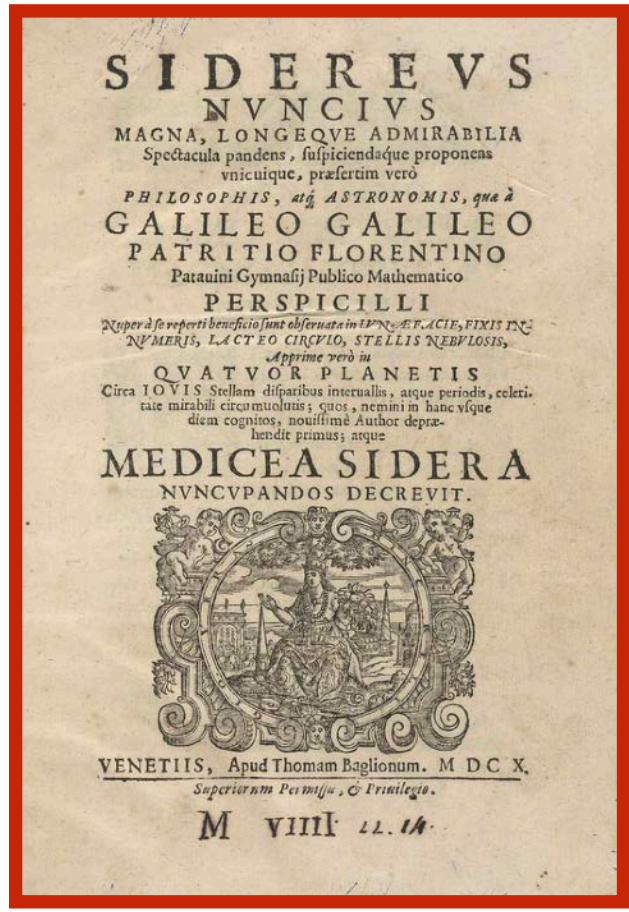
<https://twiki.cern.ch/twiki/bin/view/Main/PhatSrimanobhasTeaching>

How to measure the speed of light



Galileo Galilei

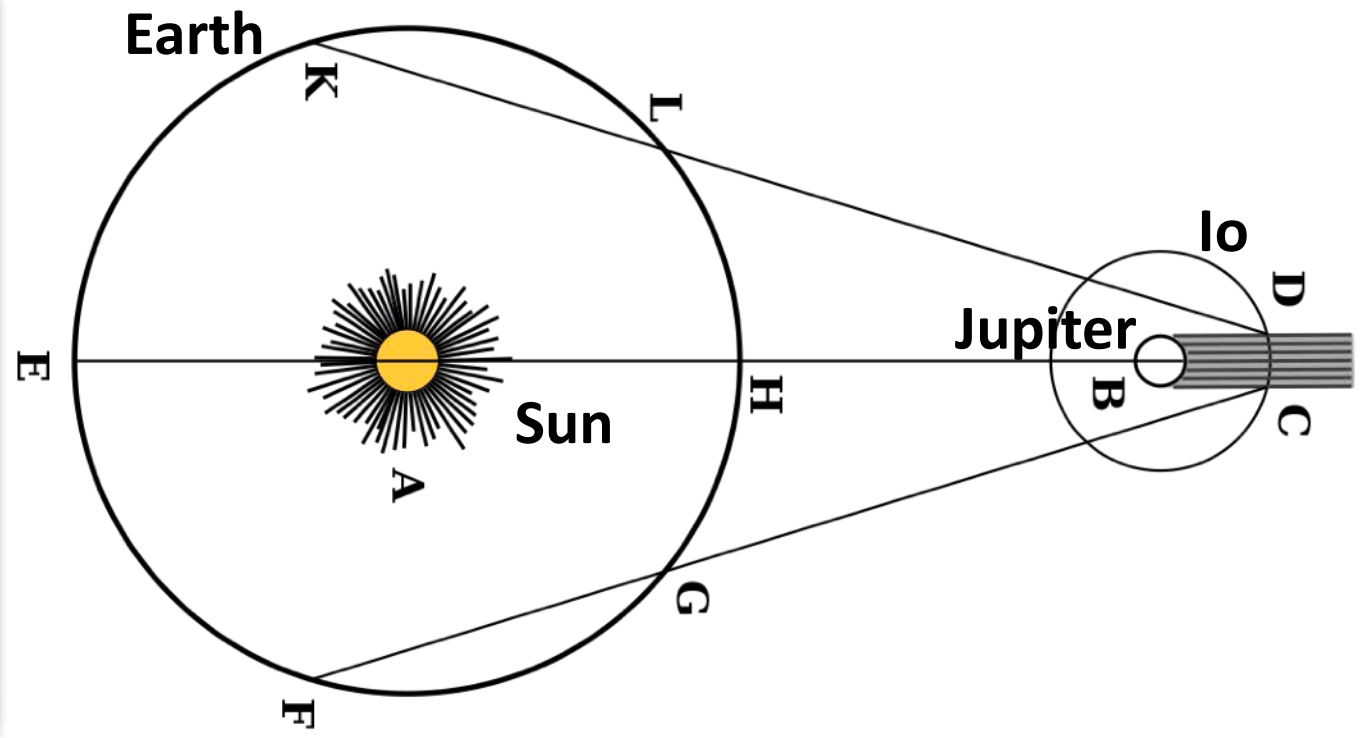
[Wiki] **Sidereus Nuncius**, the first published scientific work based on observations made through a telescope, and it contains the results of Galileo's early observations of the imperfect and mountainous Moon, the hundreds of stars that were unable to be seen in either the Milky Way or certain constellations with the naked eye, and the Medicean Stars (later Galilean moons) that appeared to be circling Jupiter.



Ole Rømer

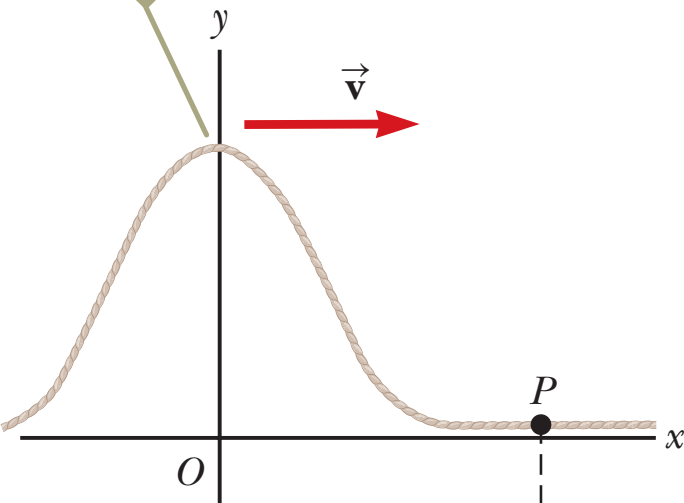


Christiaan Huygens

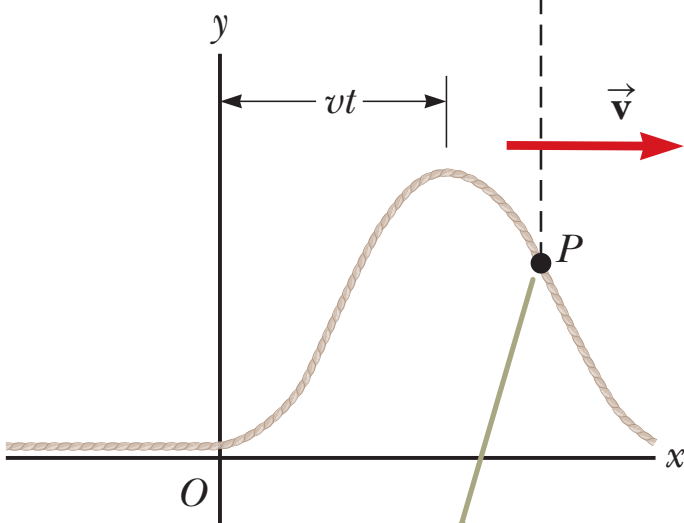


Review: Wave function and wave equation

At $t = 0$, the shape of the pulse is given by $y = f(x)$.



a



At some later time t , the shape of the pulse remains unchanged and the vertical position of an element of the medium at any point P is given by $y = f(x - vt)$.

b

Example

Show that the following functions are possible solutions of wave equation:

$$(a) y(x, t) = \ln[b(x - vt)]$$

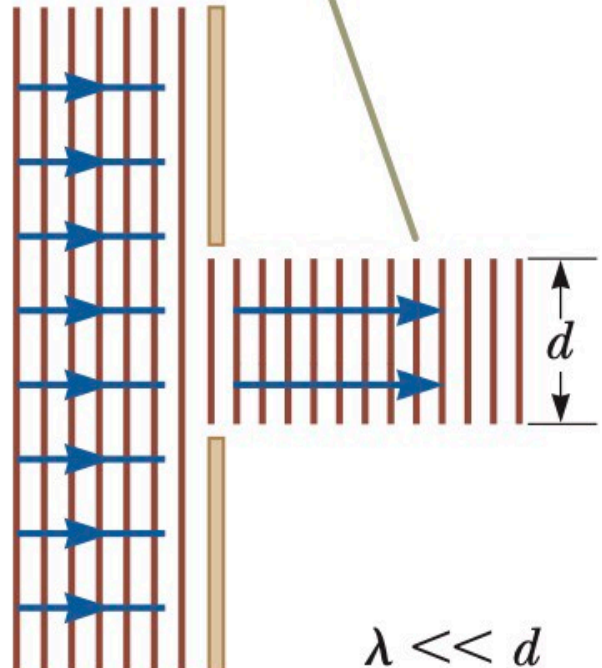
$$(b) y(x, t) = e^{b(x-vt)}$$

$$(c) y(x, t) = x^2 + v^2 t^2$$

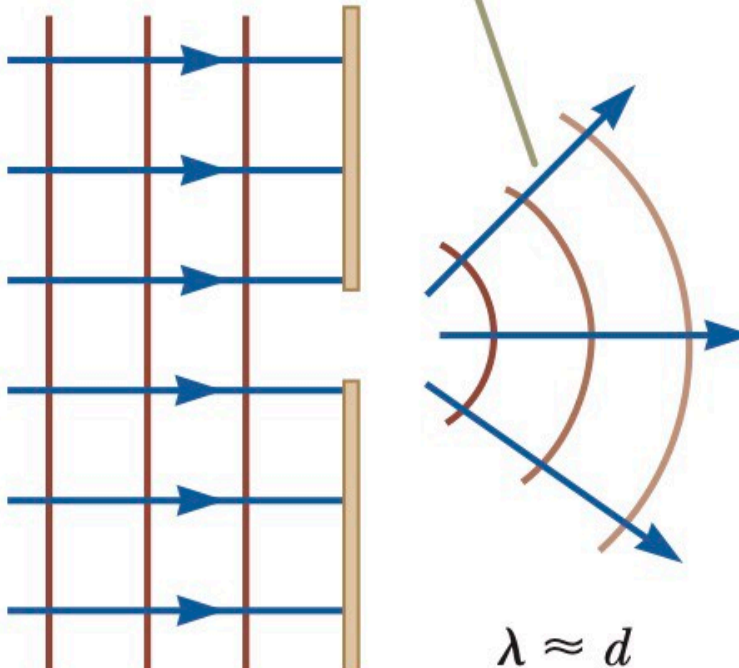
Ray optics and wave optics

A plane wave of wavelength λ is incident on a barrier in which there is an opening of diameter d .

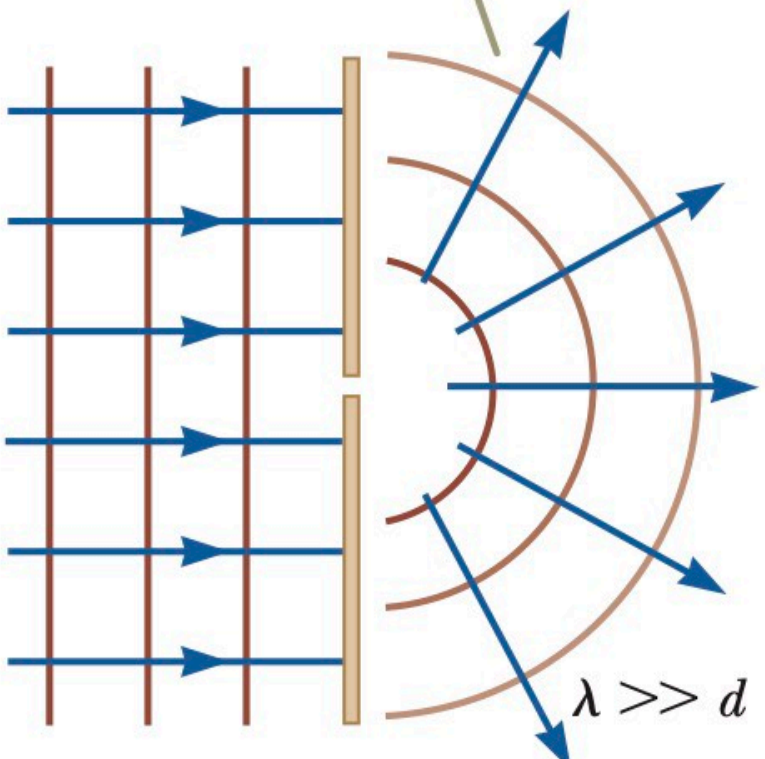
When $\lambda \ll d$, the rays continue in a straight-line path and the ray approximation remains valid.



When $\lambda \approx d$, the rays spread out after passing through the opening.

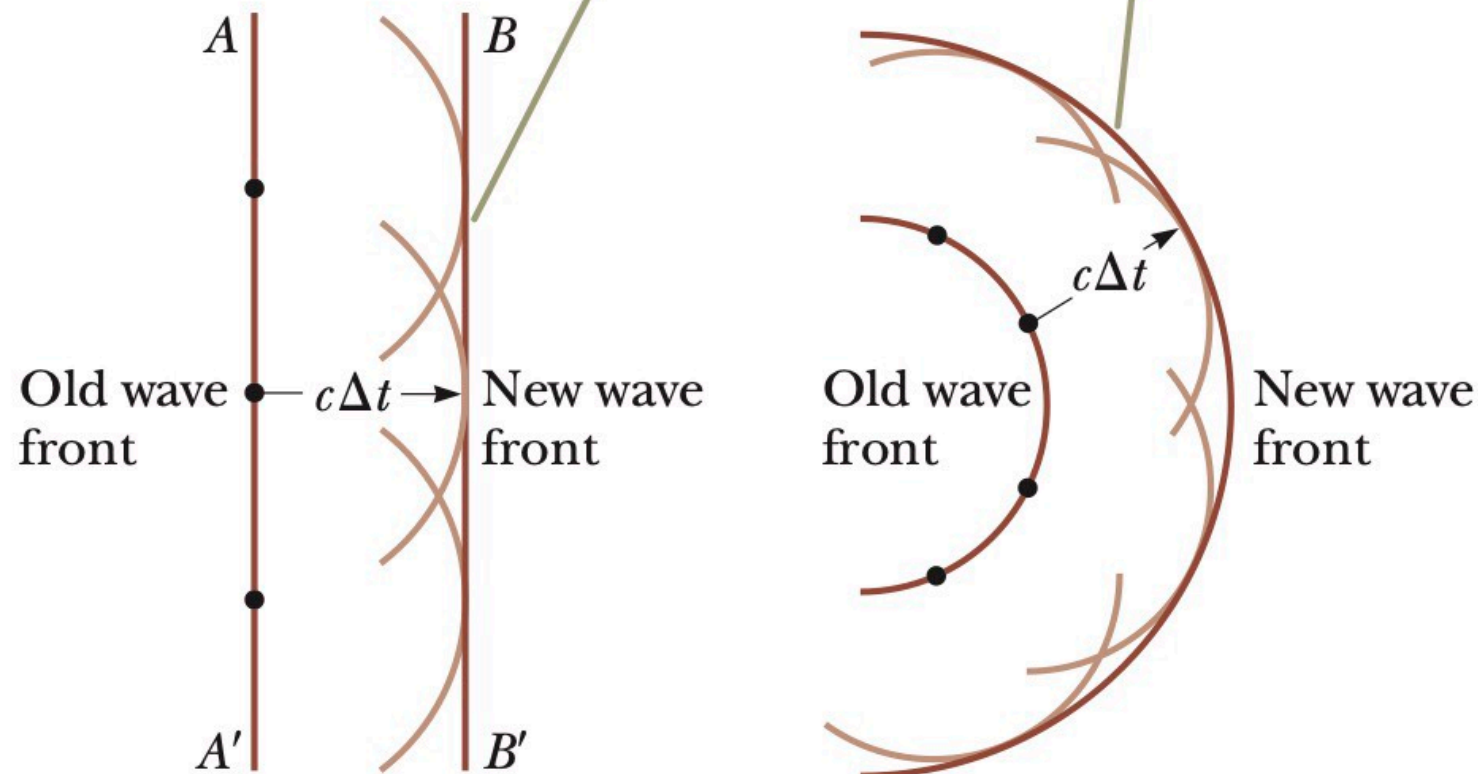


When $\lambda \gg d$, the opening behaves as a point source emitting spherical waves.



Huygens's principle

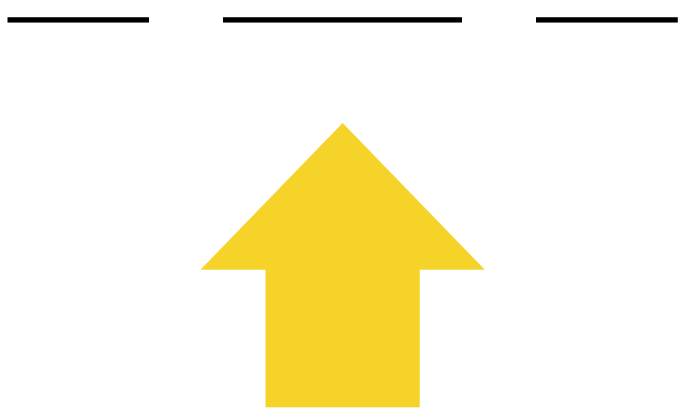
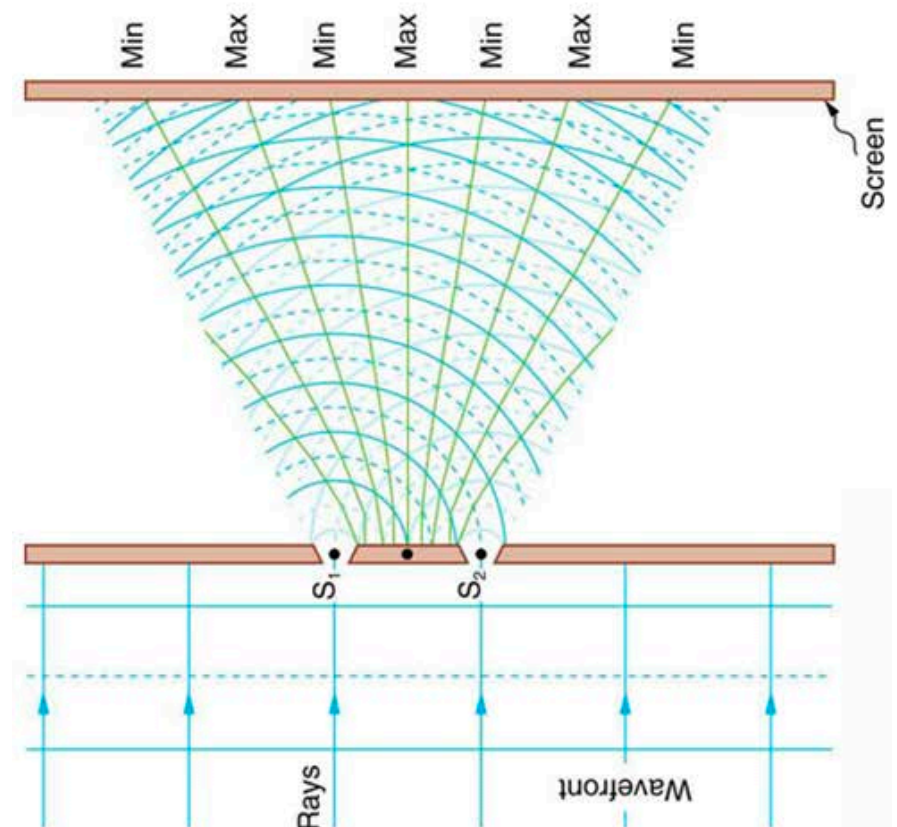
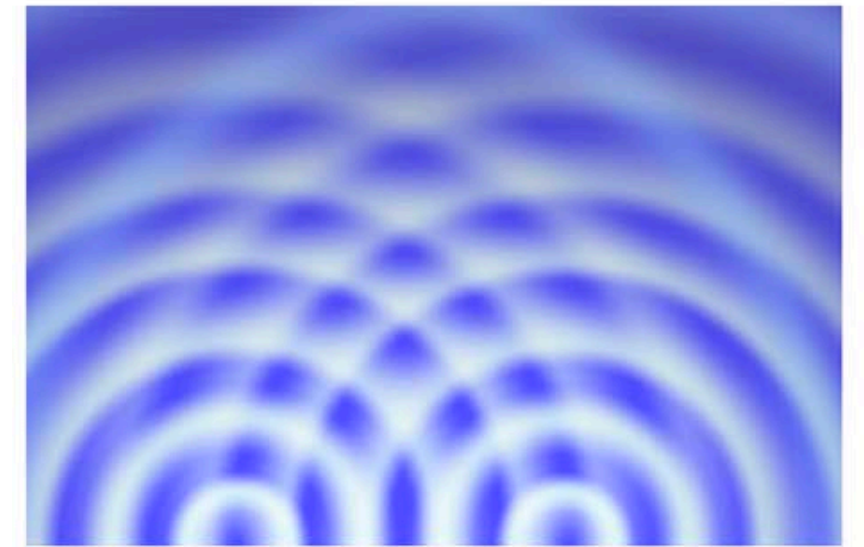
The new wave front is drawn tangent to the circular wavelets radiating from the point sources on the original wave front.



All points on a given wave front are taken as point sources for the production of spherical secondary waves, called wavelets, that propagate outward through a medium with speeds characteristic of waves in that medium. After some time interval has passed, the new position of the wave front is the surface tangent to the wavelets.

Wave equation, wave function and intensity

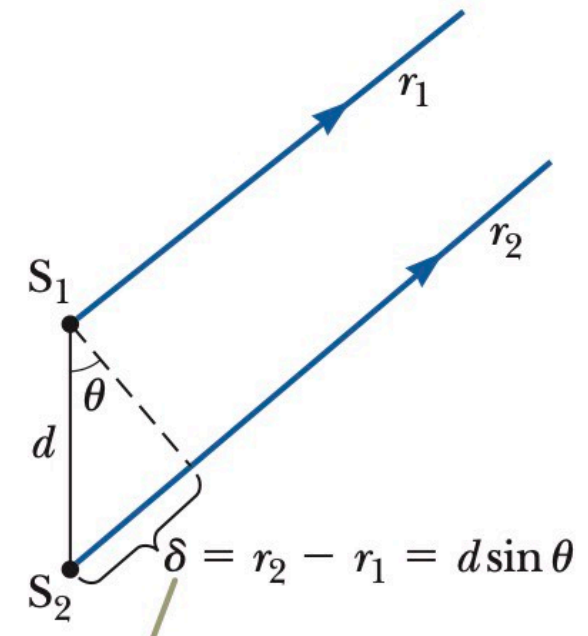
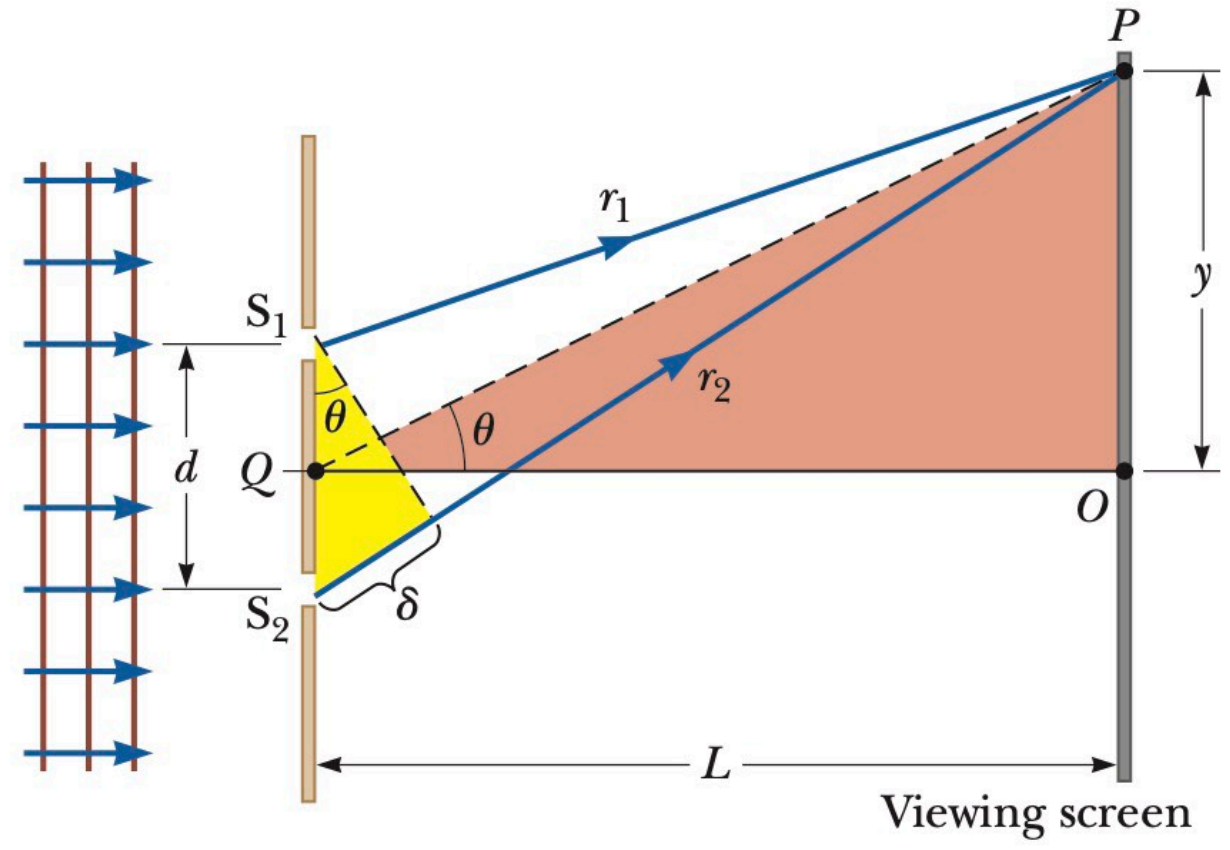
Consider the following situation, and we try to describe by using wave equation, wave function and definition of intensity we have discussed before.



Superposition of 2 waves

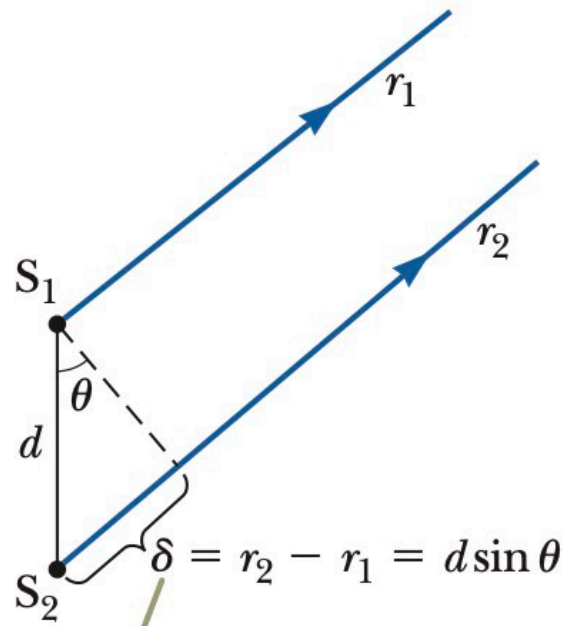
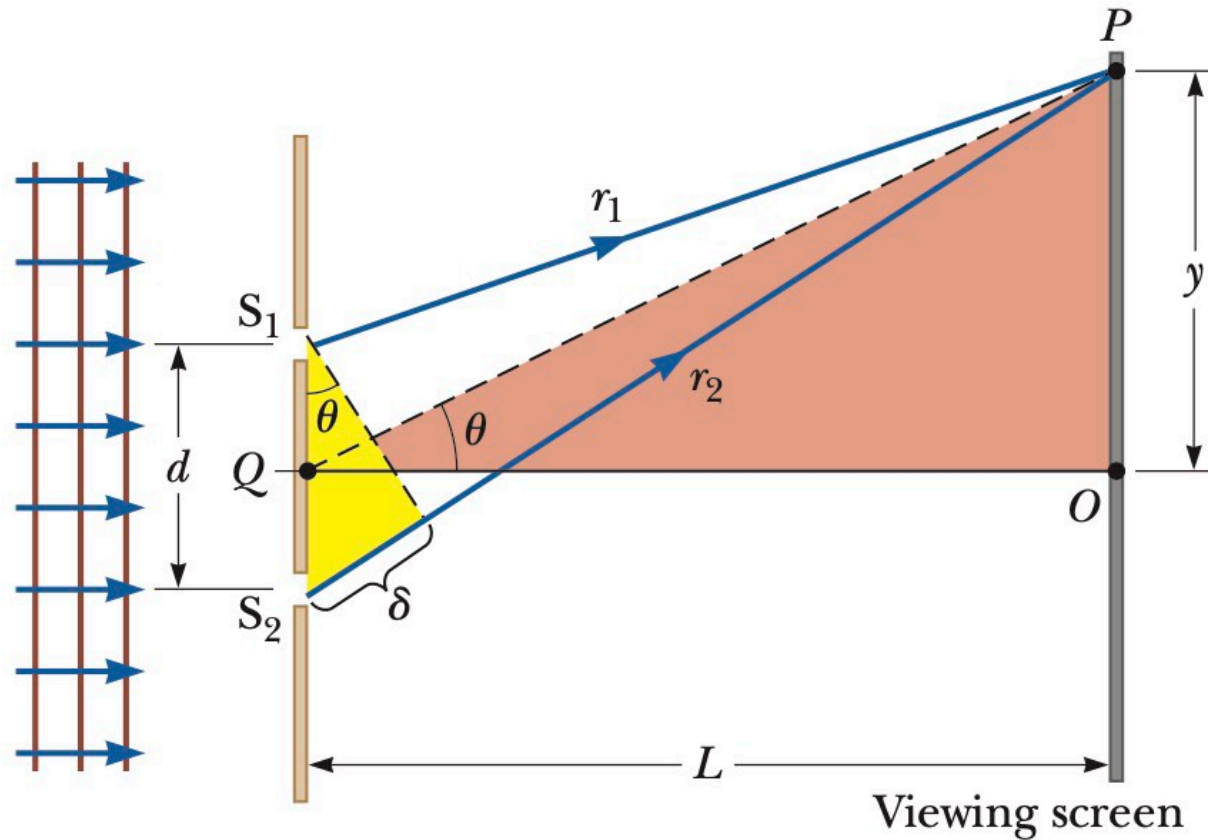
Start with 2 waves with the following wave functions: $\psi_1 = A \sin(\omega t)$ and $\psi_2 = A \sin(\omega t + \phi)$. Using the superposition principle, what will you get?

Waves in interference



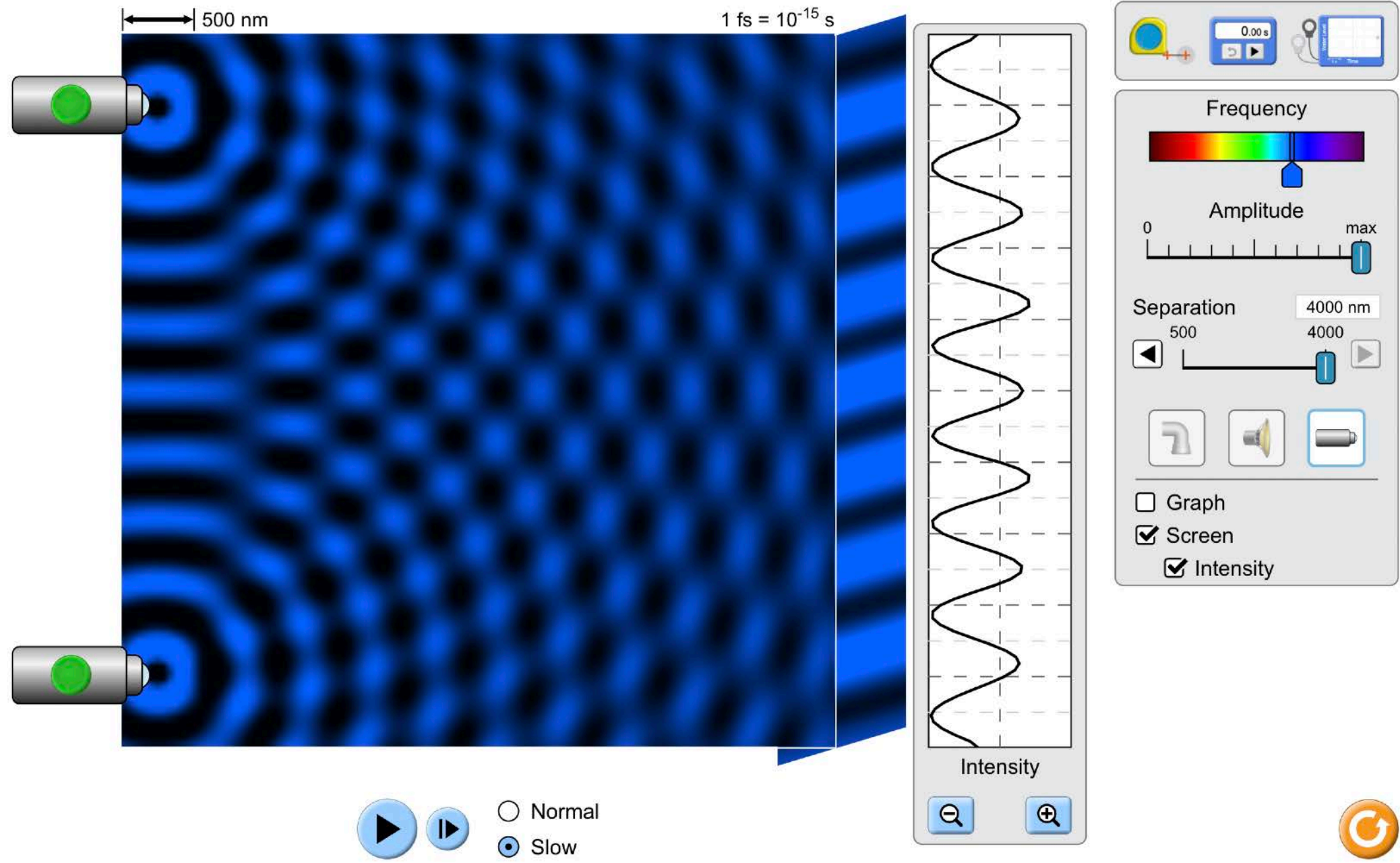
When we assume r_1 is parallel to r_2 , the path difference between the two rays is $r_2 - r_1 = d \sin \theta$.

Young's double-slit experiment



When we assume r_1 is parallel to r_2 , the path difference between the two rays is $r_2 - r_1 = d \sin \theta$.

Light intensity for double-slit interference pattern



https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html