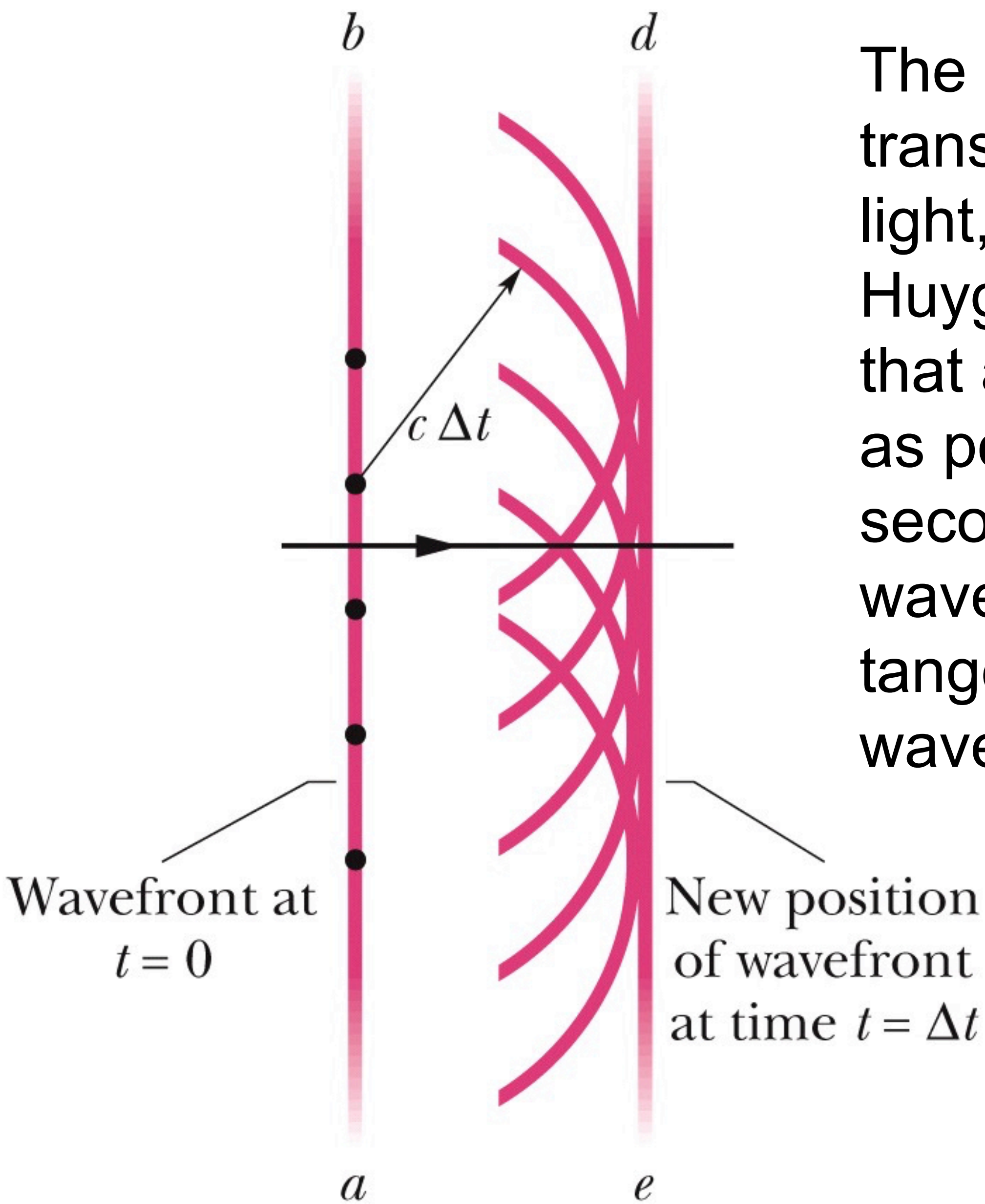
Light as a Wave and its Interferences

Light as a Wave

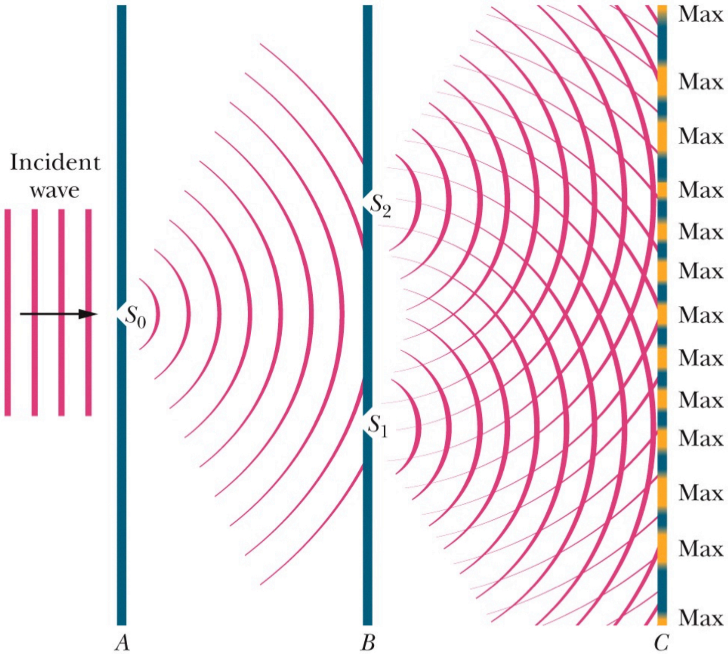


The three-dimensional transmission of waves, including light, may often be predicted by Huygens' principle, which states that all points on a wavefront serve as point sources of spherical secondary wavelets. The new wavefront will be that of the surface tangent to these secondary wavelets.

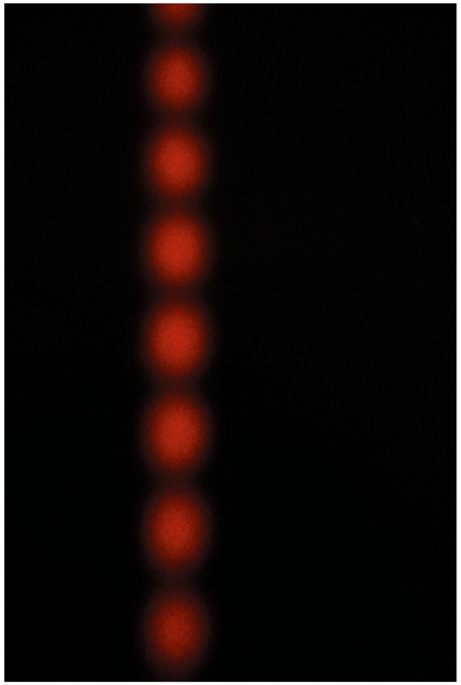
Young's double slits experiment

Coherent light (wave, that maintains a fixed phase relationship) produce fixed interference patterns.

Thomas Young's double slit experiment (1801) actually has three slits. Based on Huygens' principle, light from a distant monochromatic source illuminates slit S_0 in screen *A*. The emerging light illuminates two slits S_1 and S_2 in screen *B* to produce two coherent light sources. Coherent light from S_1 and S_2 produce interference patterns on screen *C*, demonstrating the wave characteristics of light.

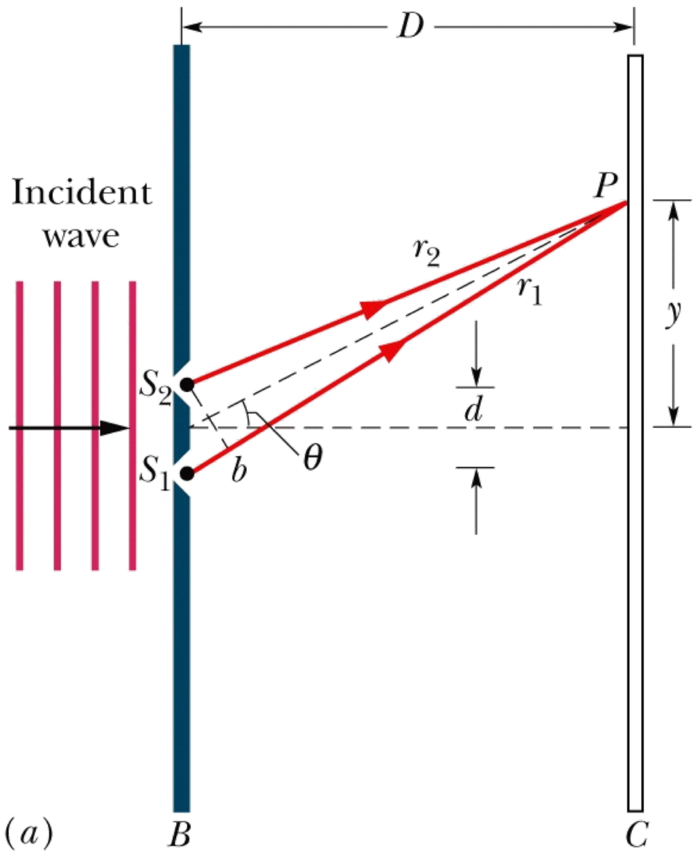


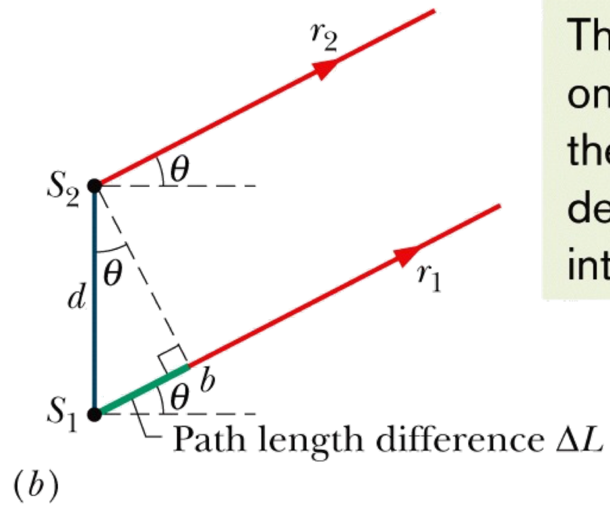
A photograph of the interference pattern of a two slit experiment. The alternating maxima and minima are called interference fringes.



Courtesy Jearl Walker

Fringe locations





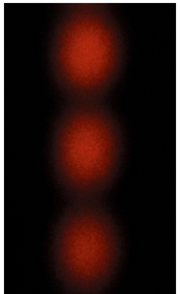
The ΔL shifts one wave from the other, which determines the interference.

(a) Waves from slits S_1 and S_2 combine at P, a point on screen C at distance *y* from the central axis. The angle *θ* serves as a convenient locator for *P*.

(b) For D >> d, we can approximate rays r_1 and r_2 as being parallel, at angle *θ* to the central axis.

maximum intensity: $d\sin\theta = m\lambda, \text{ for } m = 0,1,2,\ldots$

minimum intensity: $d\sin\theta = \left(m+\tfrac{1}{2}\right)\lambda, \text{ for } m = 0,1,2,\ldots$

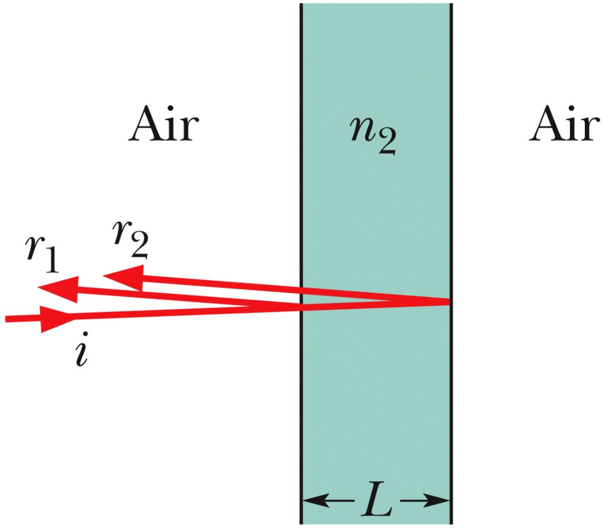


Thin film interference

When light is incident on a thin transparent film, the light waves reflected from the front and back surfaces interfere. For near-normal incidence, the wavelength conditions for

maximum: $2n_2L = \left(m + \frac{1}{2}\right)\lambda$, for $m = 0,1,2,\ldots$
and minimum: $2n_2L = m\lambda$, for $m = 0,1,2,\ldots$

intensity of the light reflected from a film with air on both sides.



Reflections from a thin film with n_2 in air.

where n_2 is the index of refraction of the film, L is its thickness, and λ is the wavelength of the light in air.

When light travels in medium 1 reflects at the interface with medium 2, the reflection causes a phase change of $\lambda/2$ (half a wavelength) in the reflected wave if $n_1 < n_2$. if $n_1 > n_2$ there is no phase change due to the reflection. Refraction causes no phase shift.

If a film is sandwiched between media other than air, these equations for bright and dark films may be interchanged, depending on the relative indexes of refraction.

Michelson's Interferometer

An interferometer is a device that can be used to measure lengths or changes in length with great accuracy by means of interference fringes.

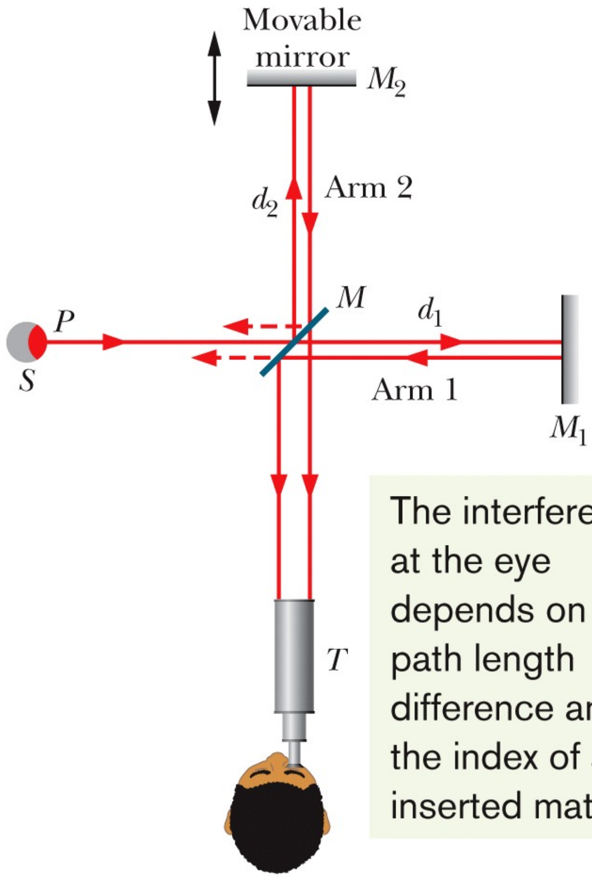
In Michelson's interferometer, a light wave is split into two beams that then recombine after traveling along different paths.

The interference pattern they produce depends on the difference in the lengths of those paths and the indexes of refraction along the paths.

If a transparent material of index n and thickness L is in one path, the phase difference (in terms of wavelength) in the recombining beams is equal to

$$\text{phase difference} = \frac{2L}{\lambda}(n-1)$$

where λ is the wavelength of the light.



The interference at the eye depends on the path length difference and the index of any inserted material.

Michelson's interferometer, showing the path of light originating at point P of an extended source S. Mirror M splits the light into two beams, which reflect from mirrors M_1 and M_2 back to M and then to telescope T. In the telescope an observer sees a pattern of interference fringes.