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2304104: GEN PHYS II
2304154: PHYS ELEC ENGS

Update: March 18, 2022

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
- The Michelson interferometer

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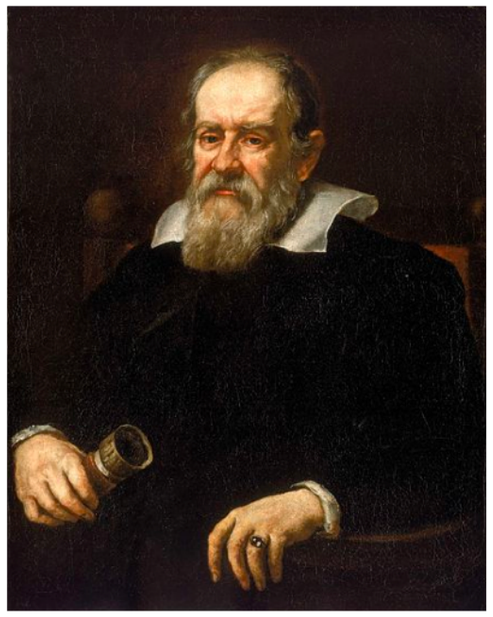
https://twiki.cern.ch/twiki/bin/view/Main/PhatSrimanobhasTeaching

How to measure the speed of light



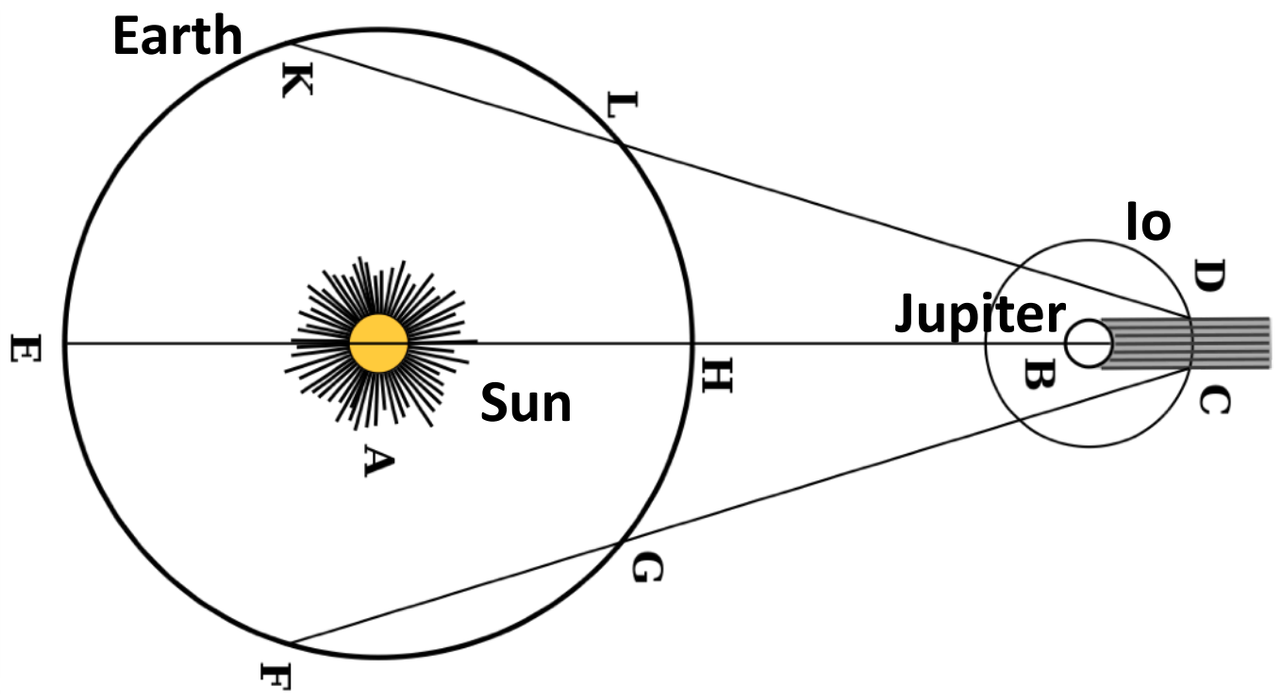
Galileo Galilei

[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.


SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in IVNÆ FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeri-
tate mirabili circumuolutis; quos, nemini in hanc vsque
diem cognitos, nouissimè Author depræ-
hendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.
M VIIII LL. IN

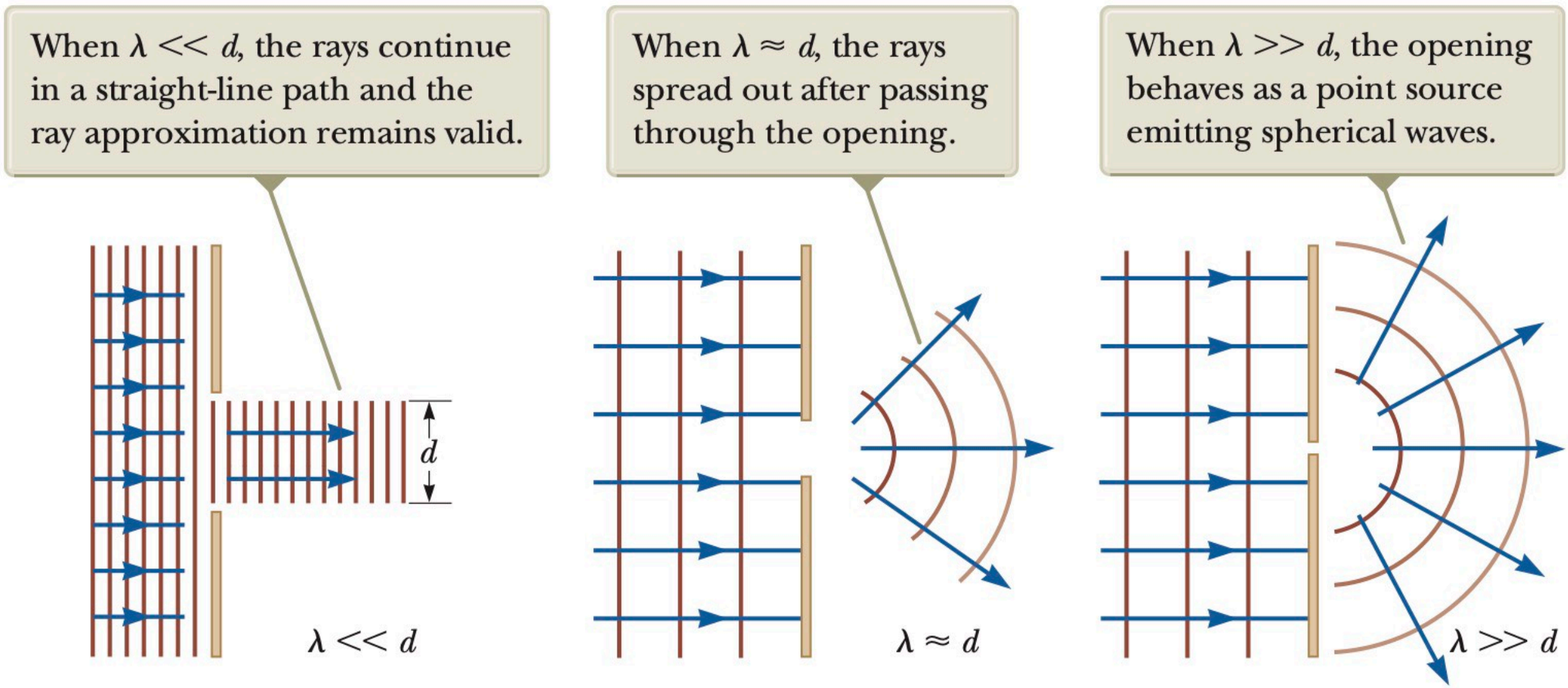
Ole Rømer

Christiaan Huygens

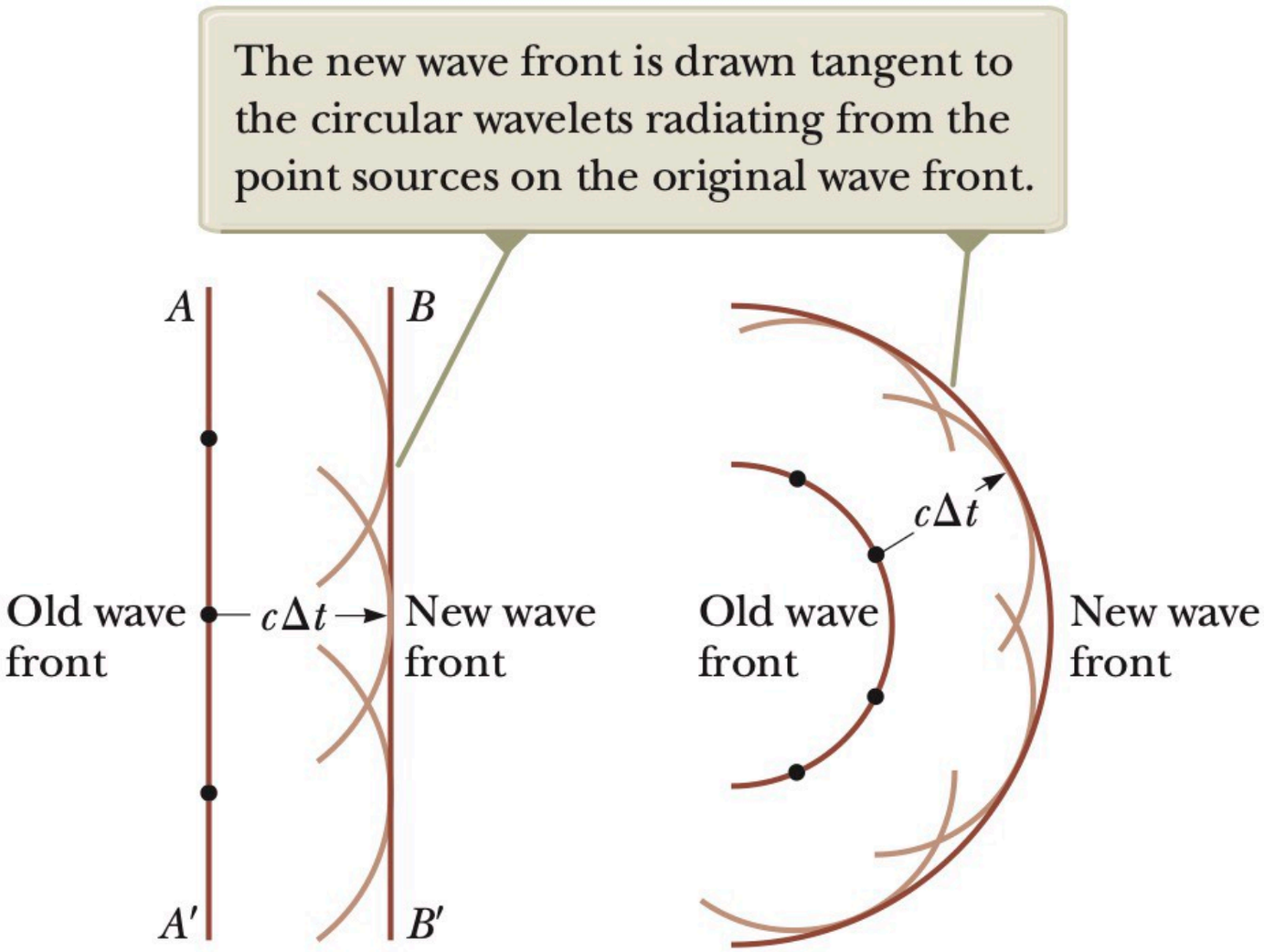


Ray optics and wave optics

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



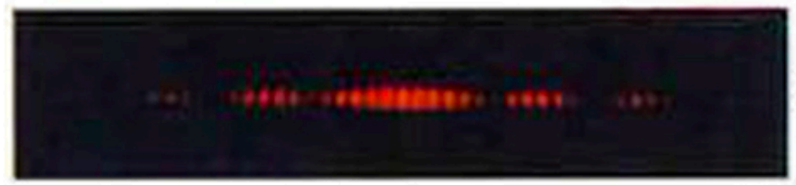
Huygens's principle

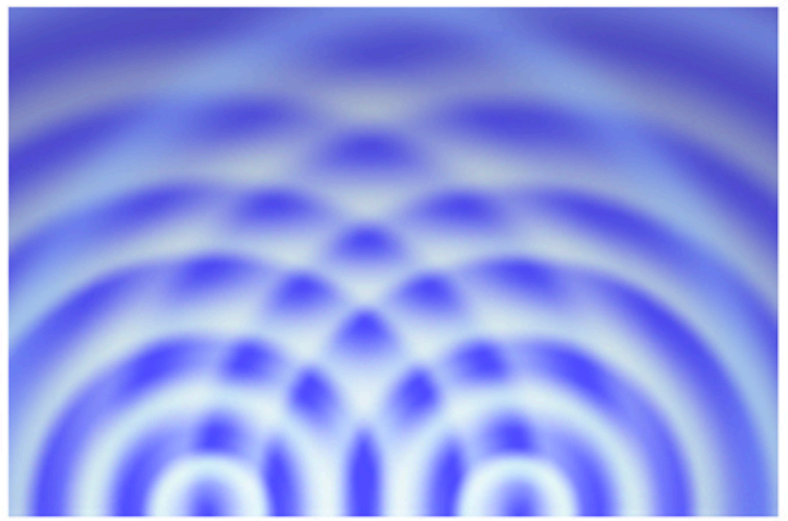


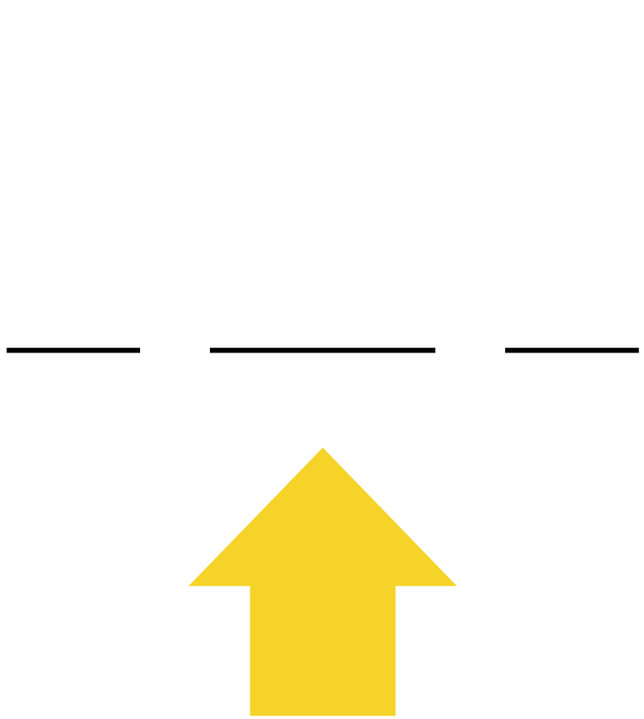
All points on a given wave front are taken as point sources for the production of spherical secondary waves, called wavelets, that propagate outward through a medium with speeds characteristic of wages in that medium. After some time interval has passed, the new position of the wave front is the surface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

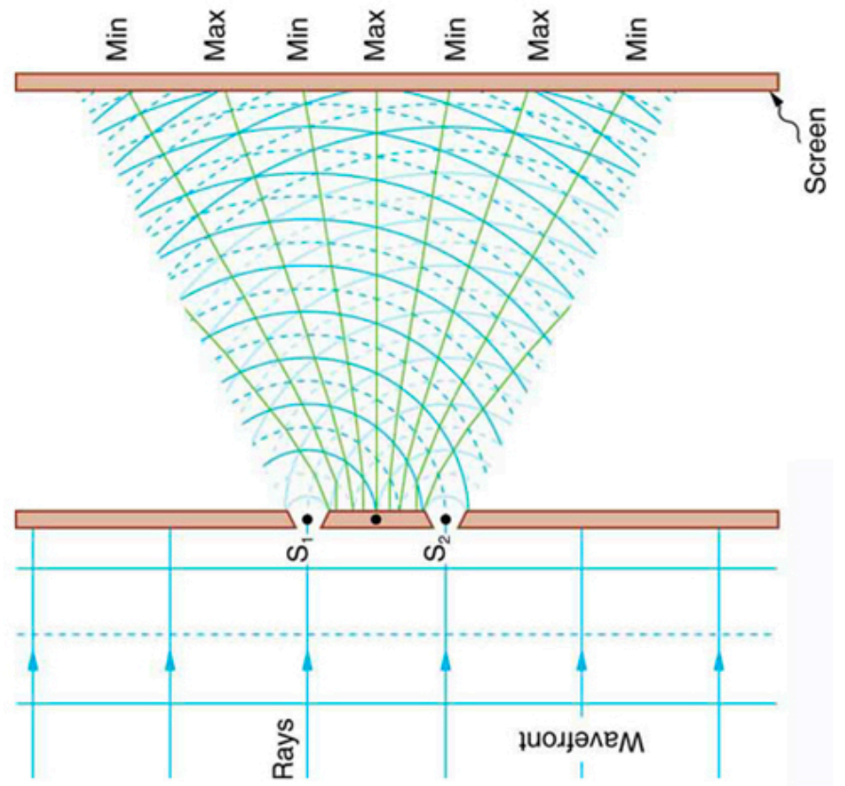
Wave equation, wave function and intensity

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





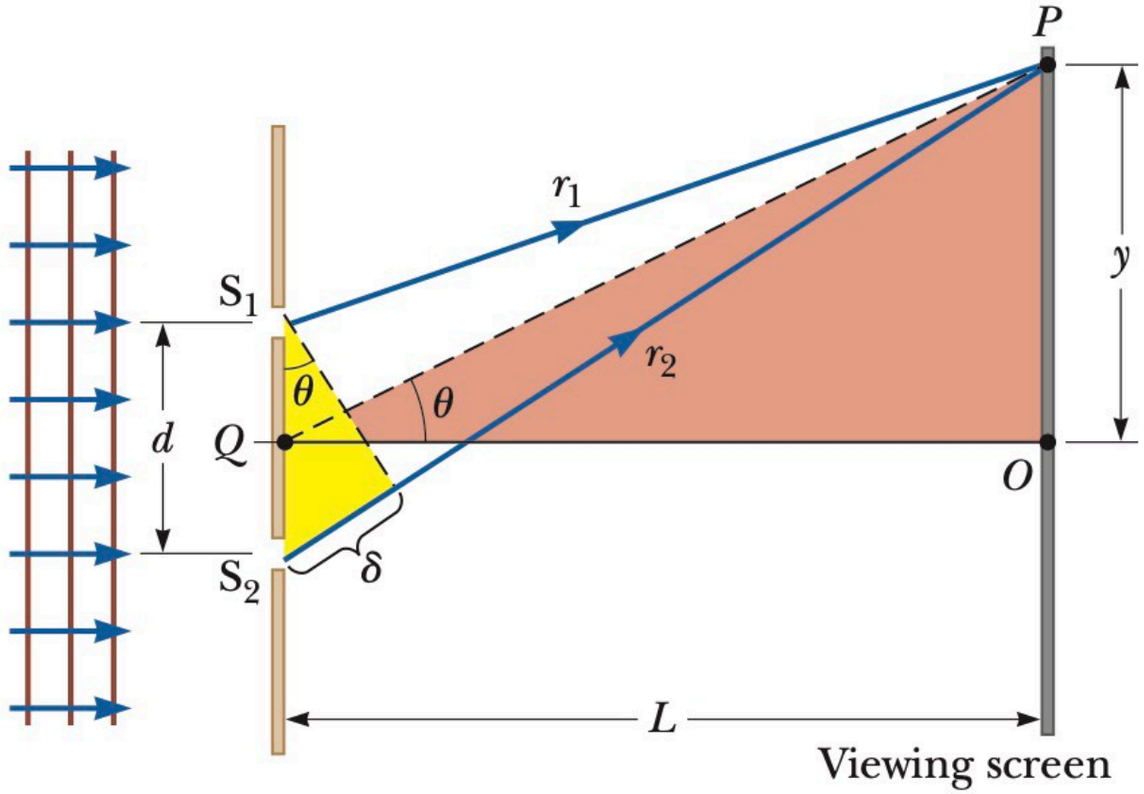


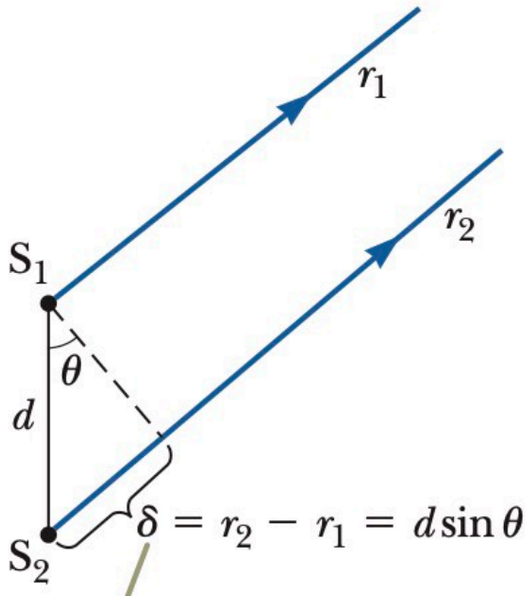


Superposition of 2 waves

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?

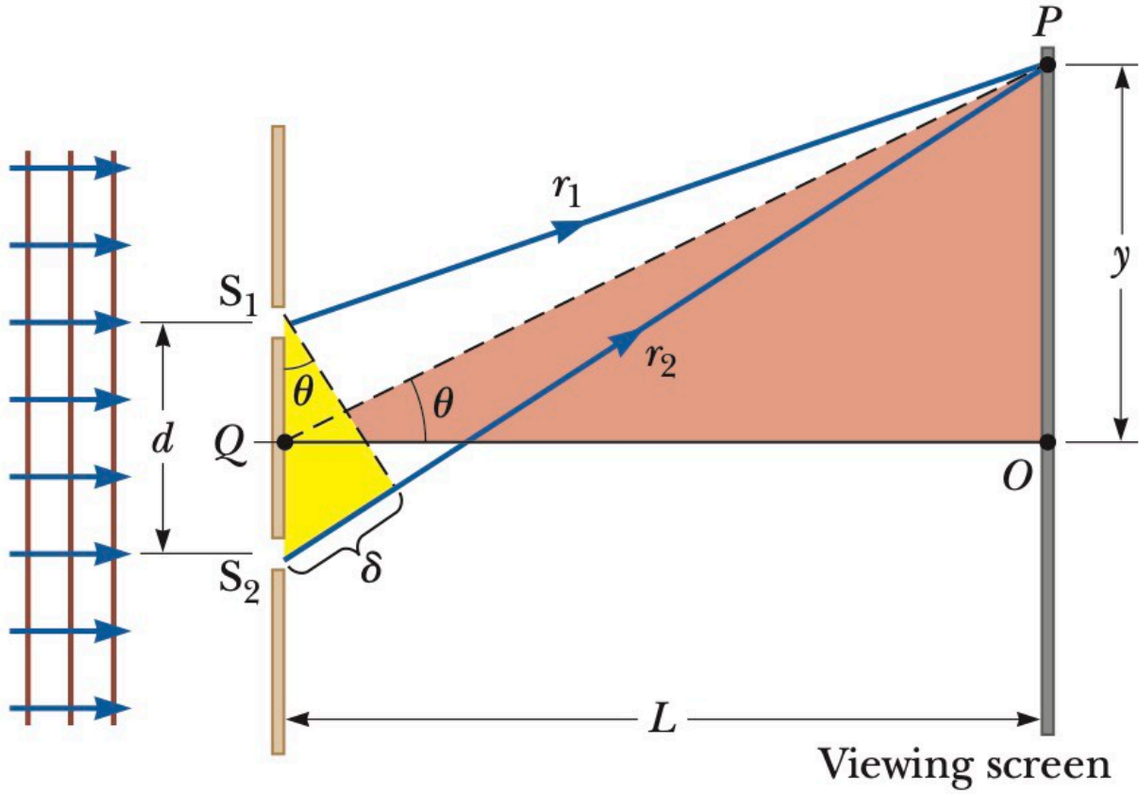
Waves in interference

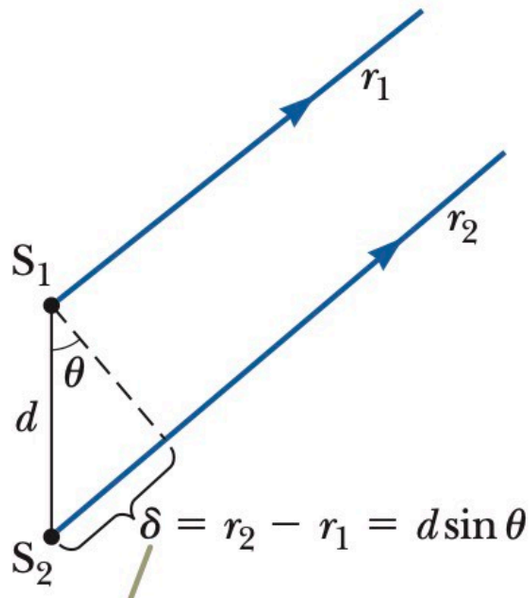




When we assume r_1 is parallel to r_2, the path difference between the two rays is $r_2 - r_1 = d\sin\theta$.

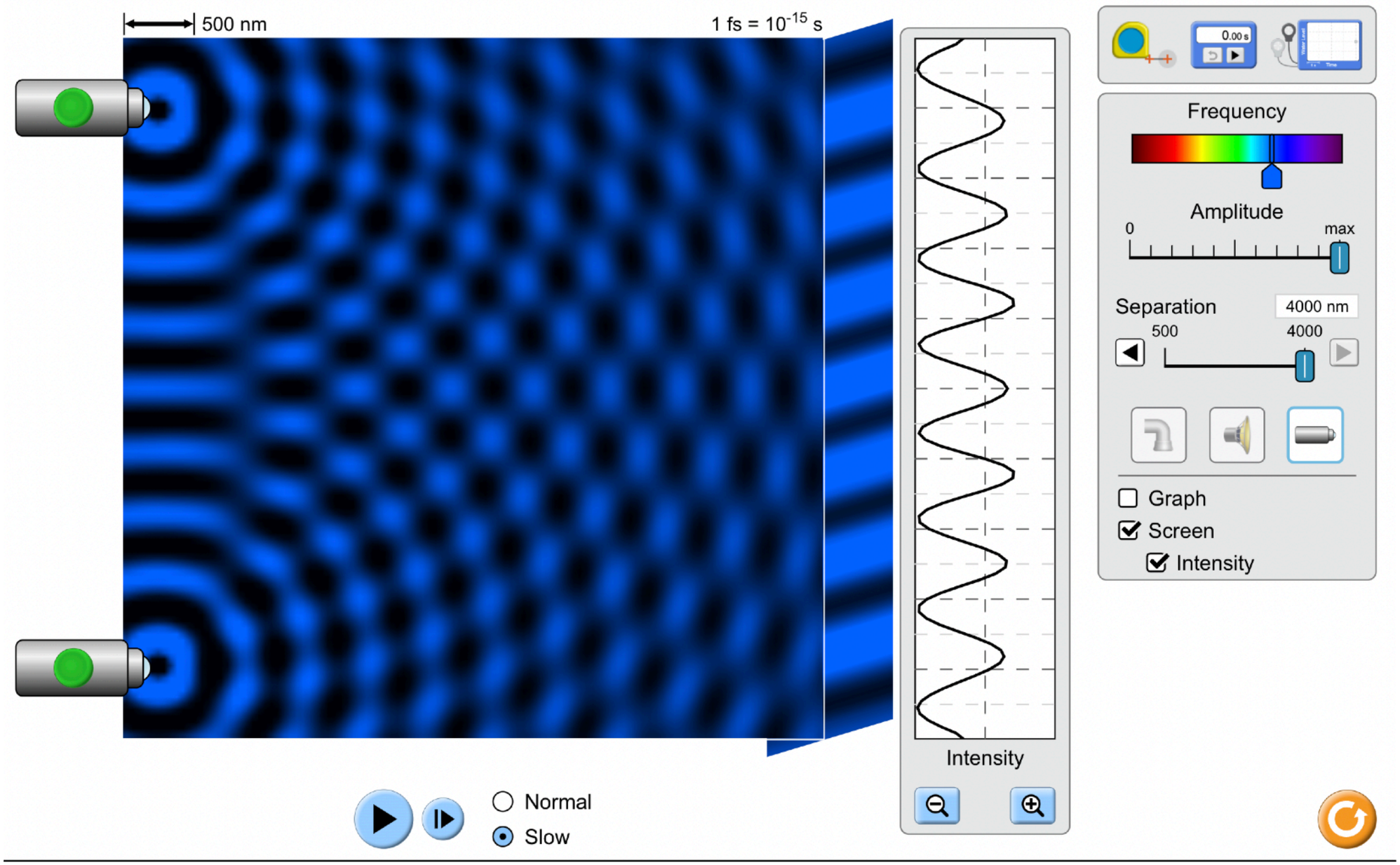
Young's double-slit experiment





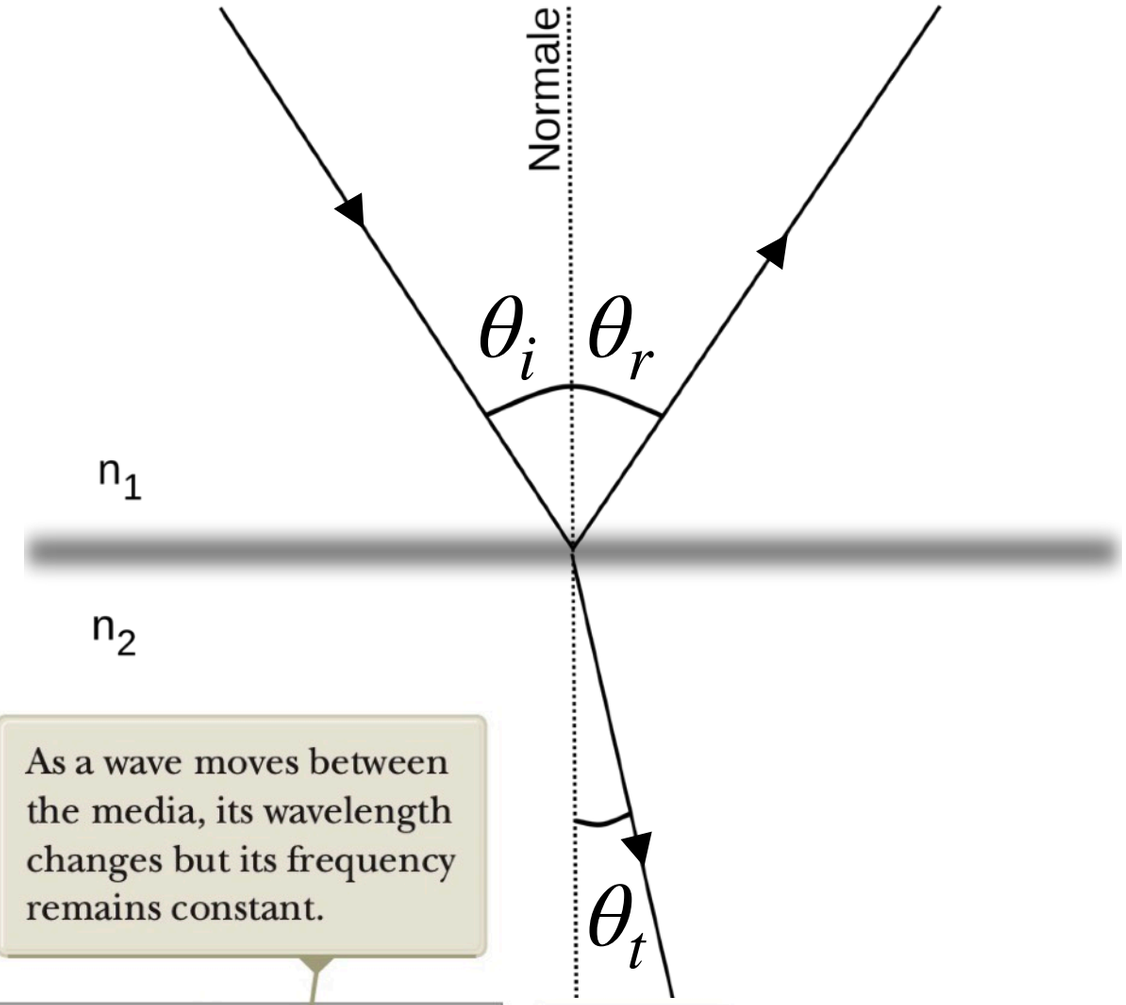
When we assume r_1 is parallel to r_2, the path difference between the two rays is $r_2 - r_1 = d\sin\theta$.

Light intensity for double-slit interference pattern



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

Review: Reflection and refraction



As a wave moves between the media, its wavelength changes but its frequency remains constant.

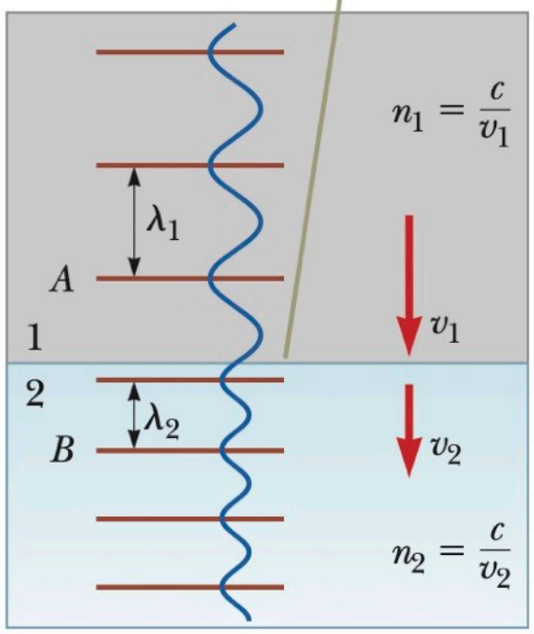
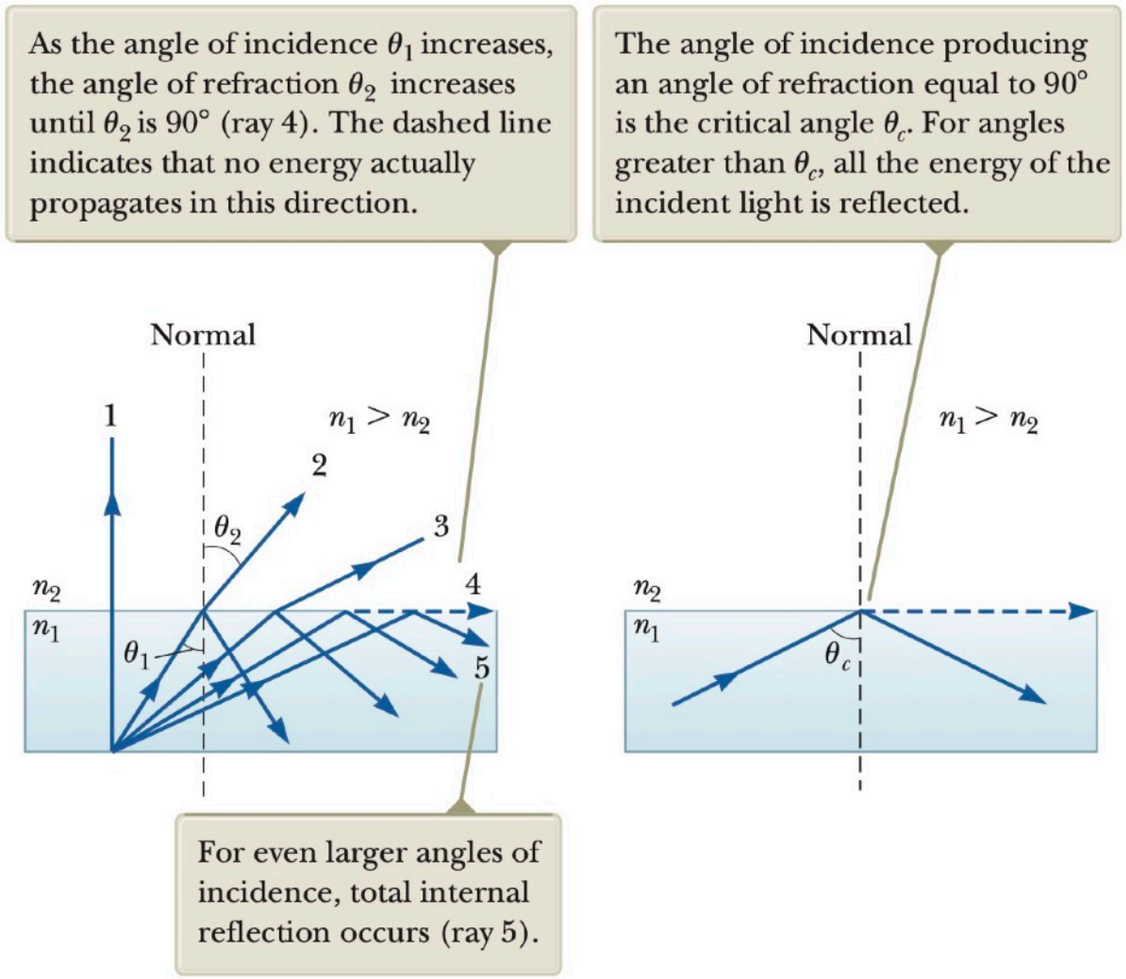


Table 35.1 Indices of Refraction

Substance	Index of Refraction	Substance	Index of Refraction
Solids at 20°C		*Liquids at 20°C*	
Cubic zirconia	2.20	Benzene	1.501
Diamond (C)	2.419	Carbon disulfide	1.628
Fluorite (CaF_2)	1.434	Carbon tetrachloride	1.461
Fused quartz (SiO_2)	1.458	Ethyl alcohol	1.361
Gallium phosphide	3.50	Glycerin	1.473
Glass, crown	1.52	Water	1.333
Glass, flint	1.66		
Ice (H_2O)	1.309	*Gases at 0°C, 1 atm*	
Polystyrene	1.49	Air	1.000 293
Sodium chloride (NaCl)	1.544	Carbon dioxide	1.000 45

Note: All values are for light having a wavelength of 589 nm in vacuum.

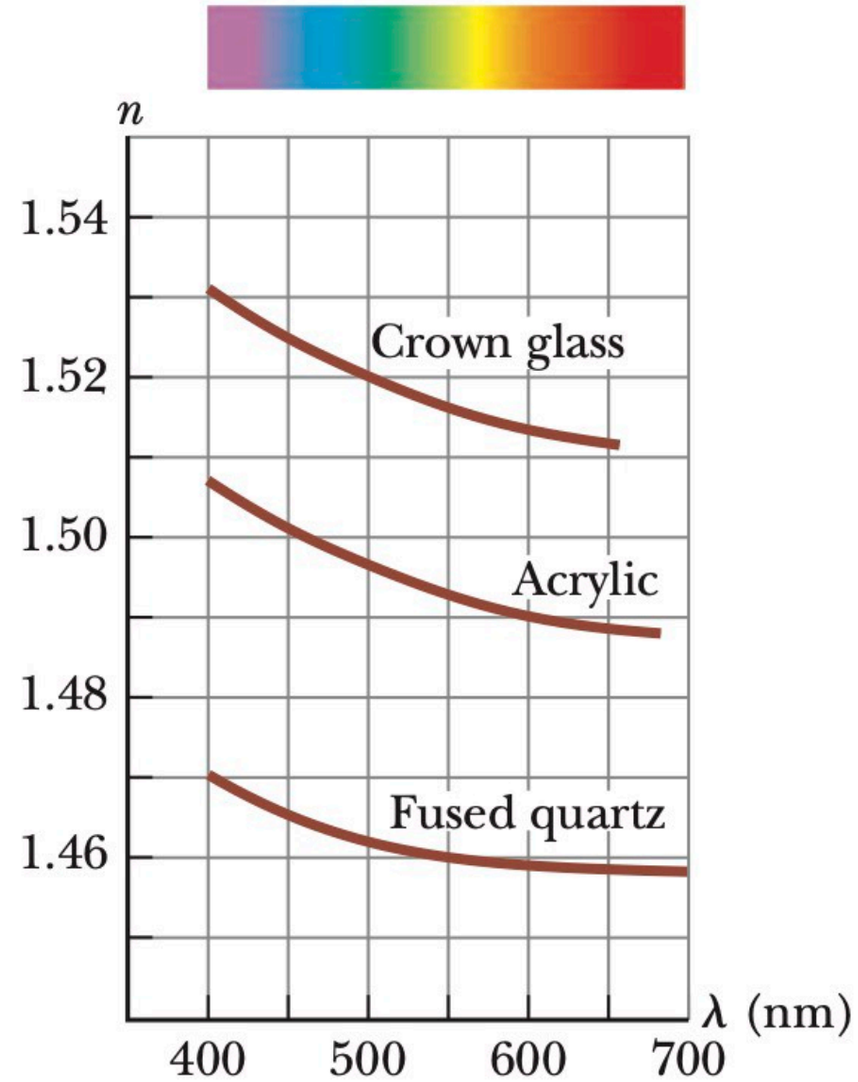
Review: Total internal reflection

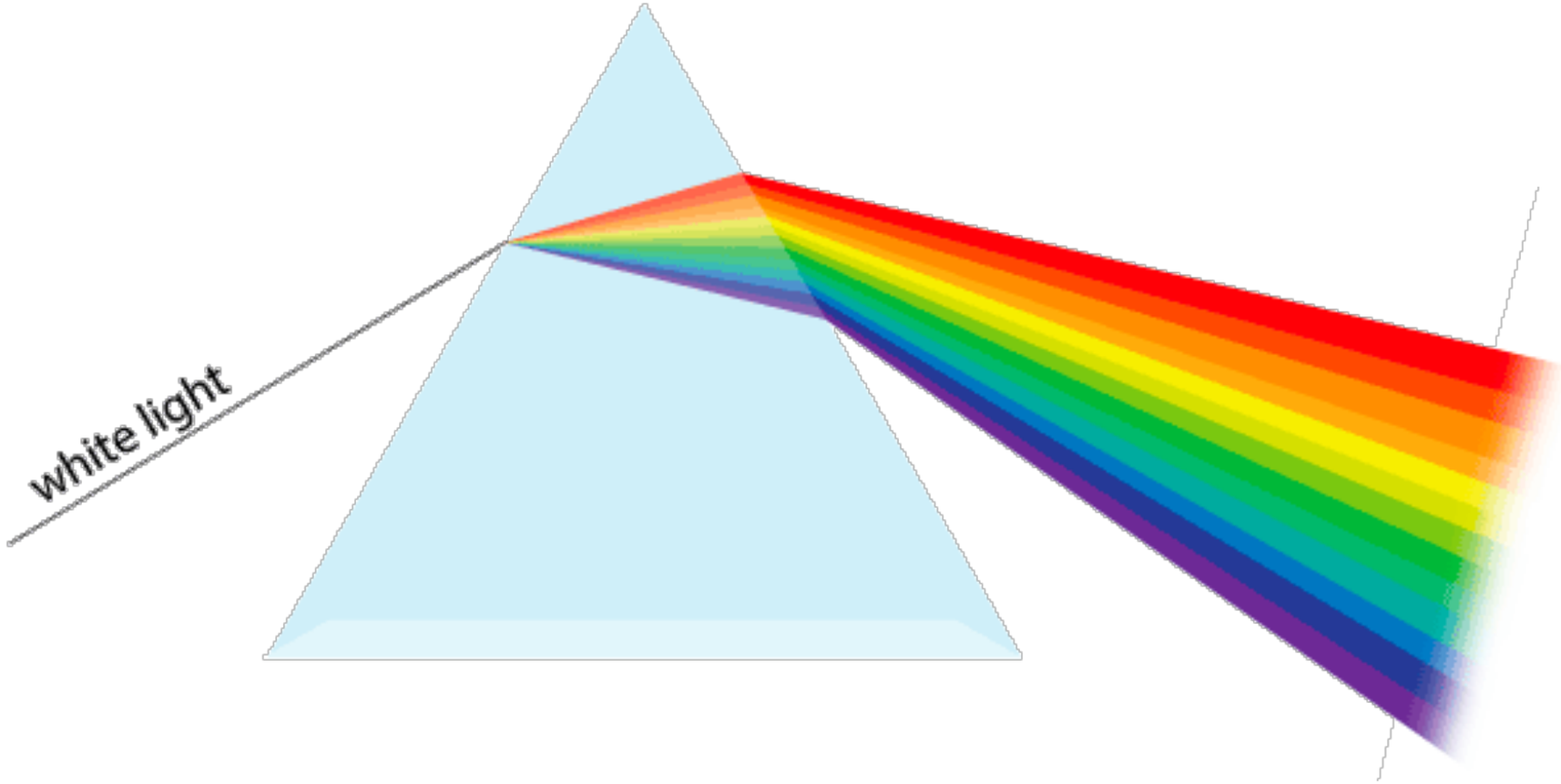


When light is incident upon a medium of lesser index of refraction, the ray is bent away from the normal, so the exit angle is greater than the incident angle. Such reflection is commonly called "internal reflection". The exit angle will then approach 90° for some critical incident angle θc, and for incident angles greater than the critical angle there will be total internal reflection.

Review: Dispersion

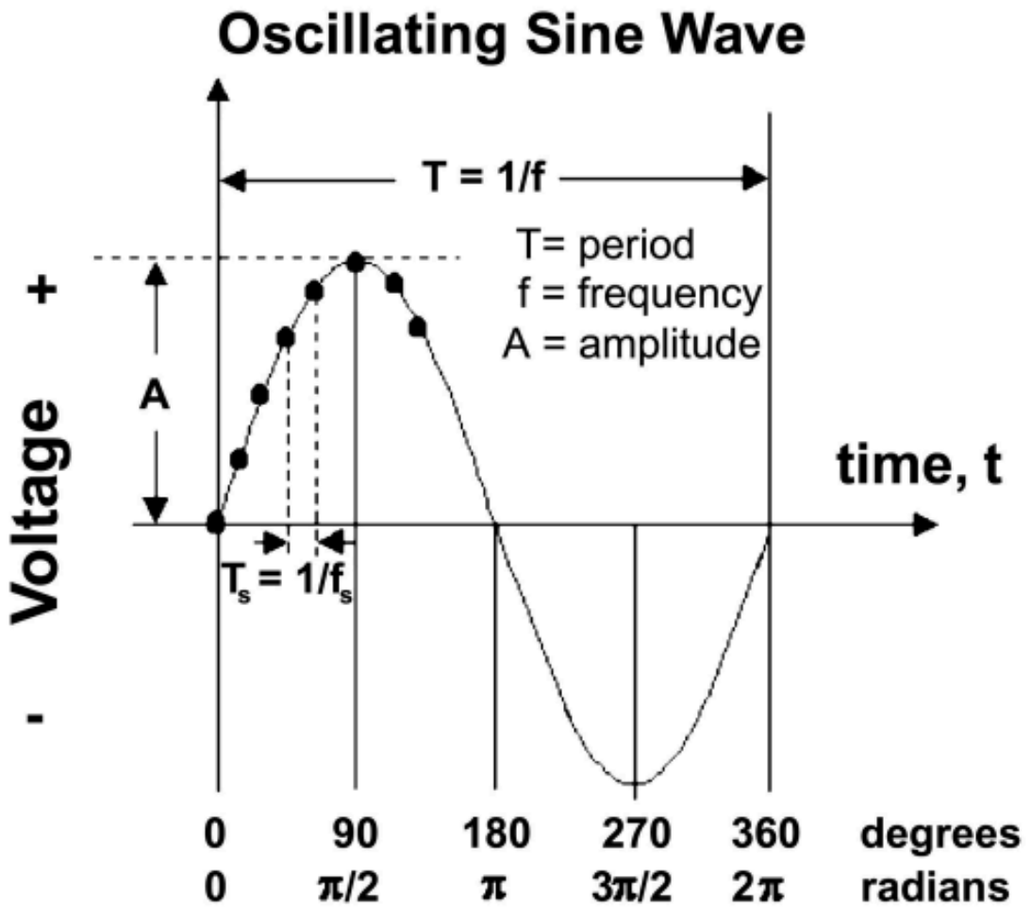
Chromatic dispersion is the change of index of refraction with wavelength. Generally the index decreases as wavelength increases. Dispersion is the phenomenon which gives you the separation of colors in a prism.

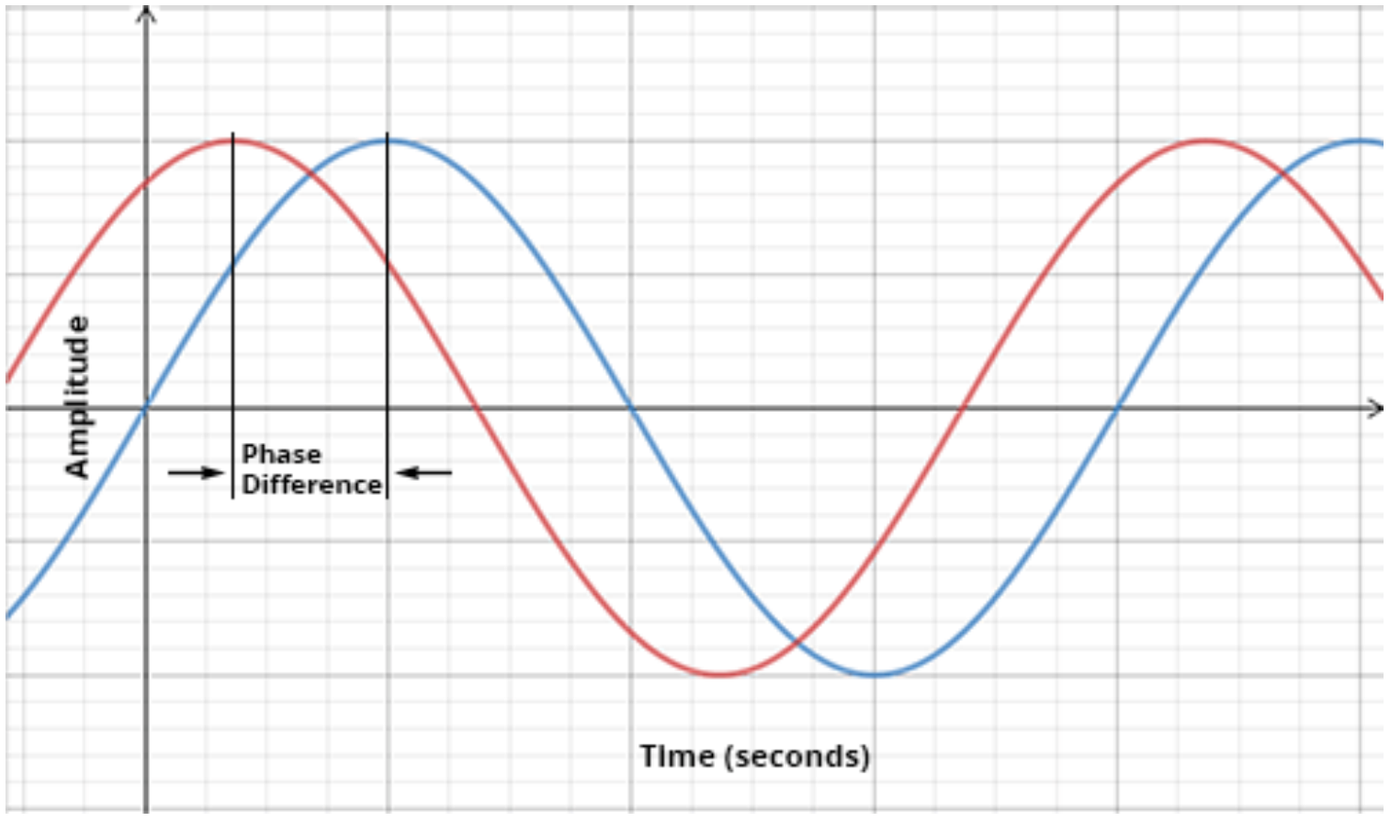




Review: phase and phase difference

Phase specifies the location or timing of a point within a wave cycle of a repetitive waveform. Typically, it is the phase difference between waves that is relevant, rather than the actual absolute phases of the signals.

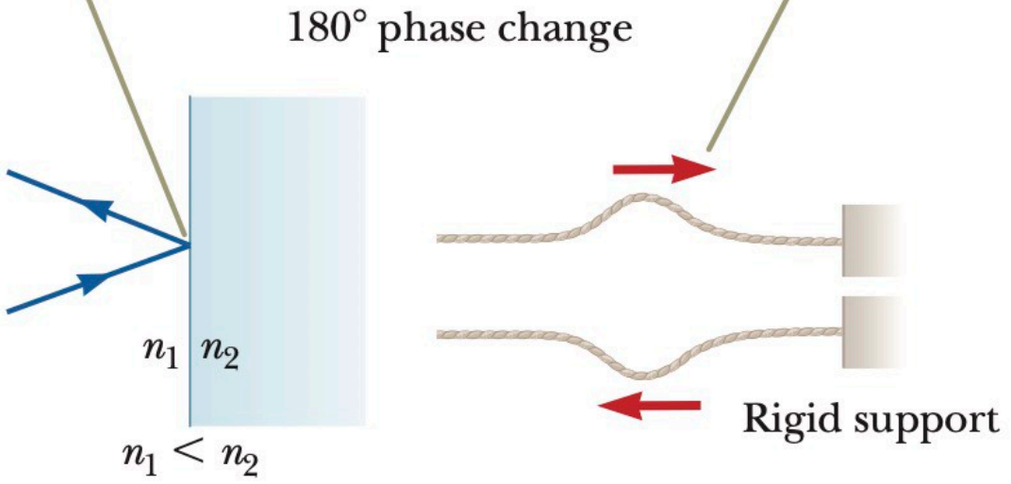




Change of phase due to reflection

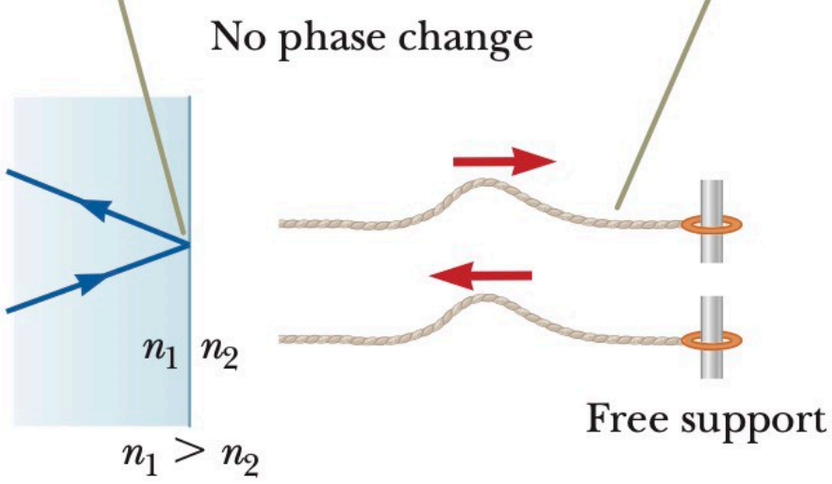
For $n_1 < n_2$, a light ray traveling in medium 1 undergoes a 180° phase change when reflected from medium 2.

The same thing occurs when a pulse traveling on a string reflects from a fixed end of the string.

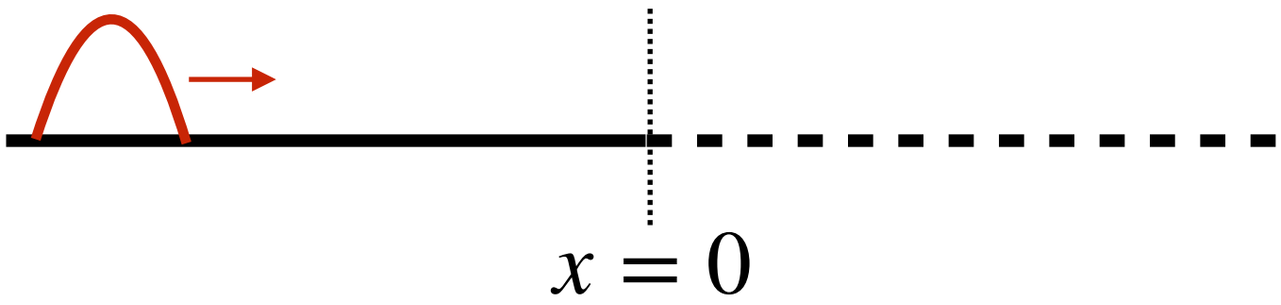


For $n_1 > n_2$, a light ray traveling in medium 1 undergoes no phase change when reflected from medium 2.

The same is true of a pulse reflected from the end of a string that is free to move.



Consider a string which made up of two string with different mass per unit length. How does wave propagate on it?



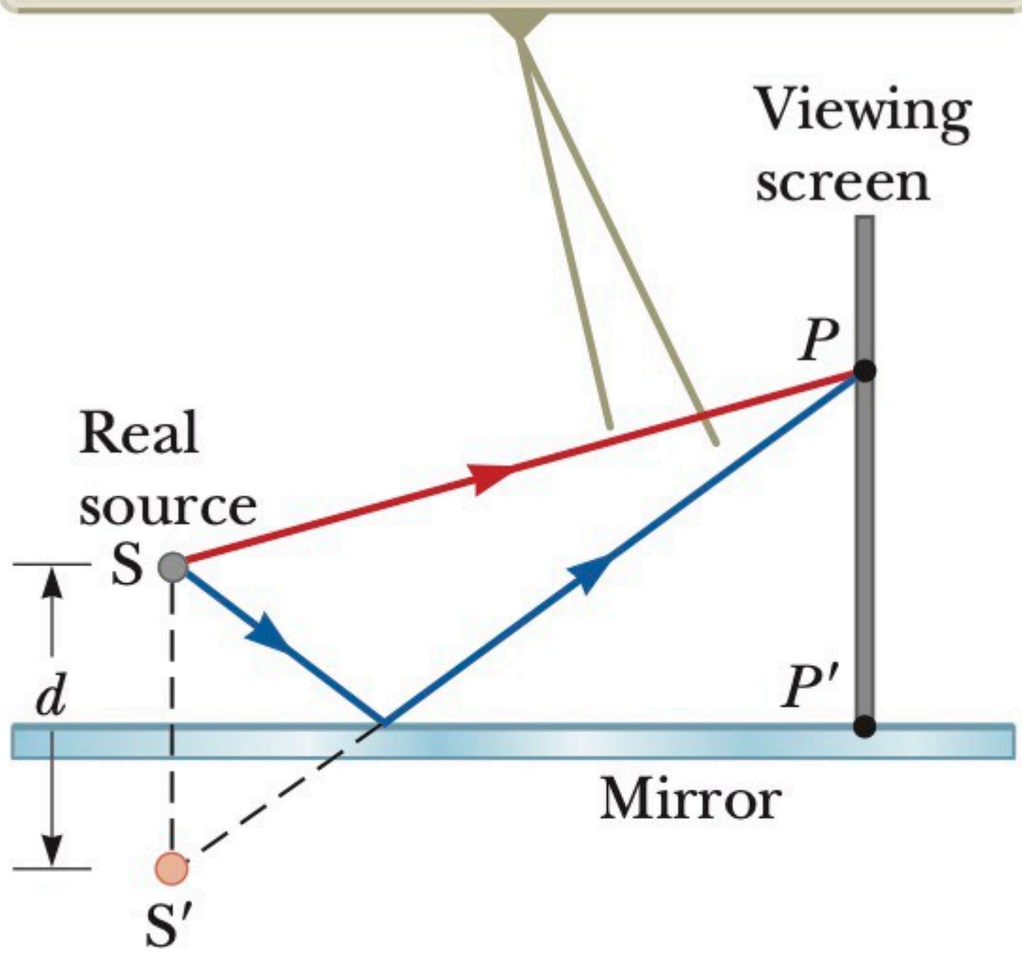
Change of phase due to reflection

Lloyd's mirror

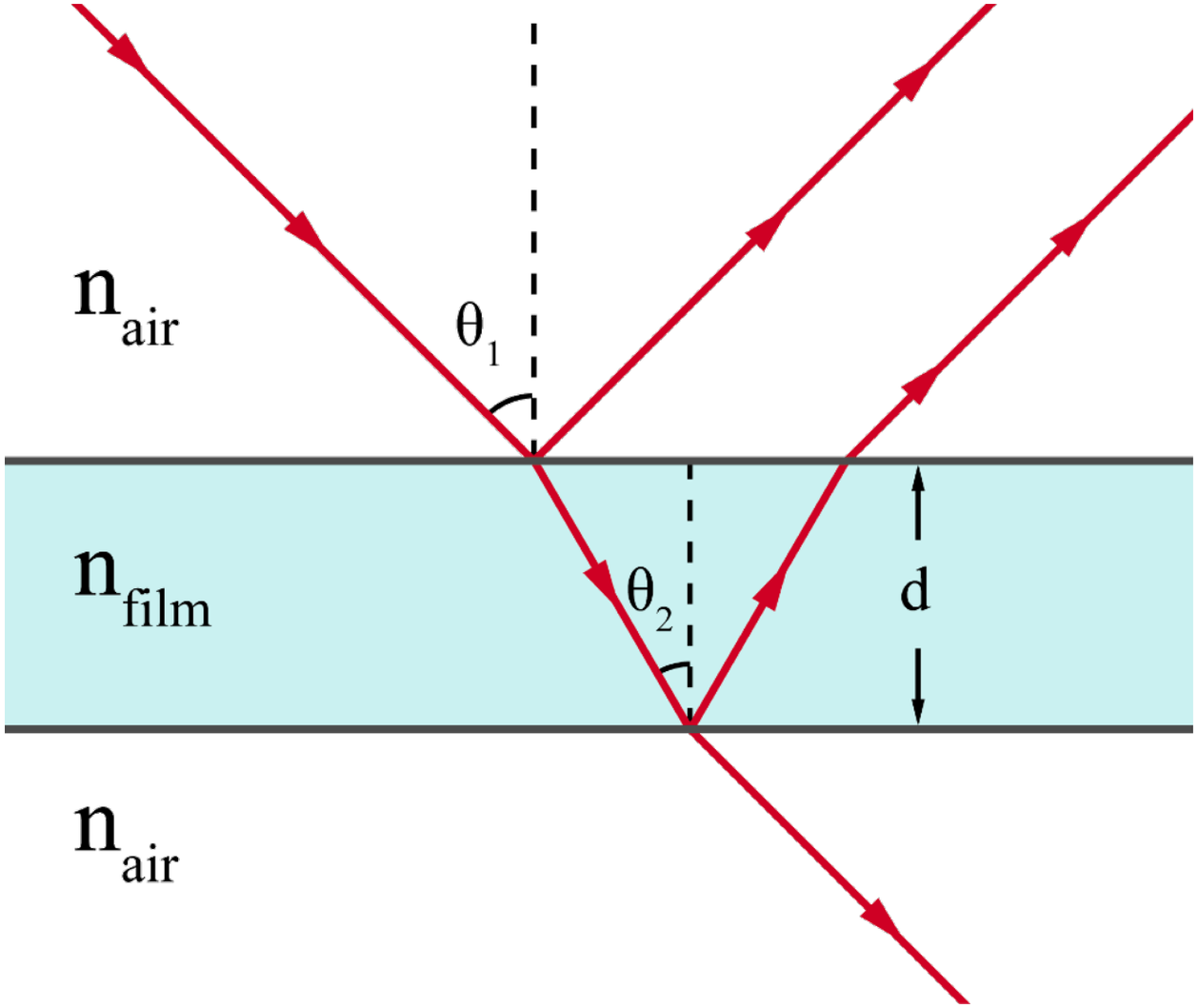
What are the differences from Young's experiment?

Humphrey Lloyd

An interference pattern is produced on the screen as a result of the combination of the direct ray (red) and the reflected ray (blue).



Interference in thin films

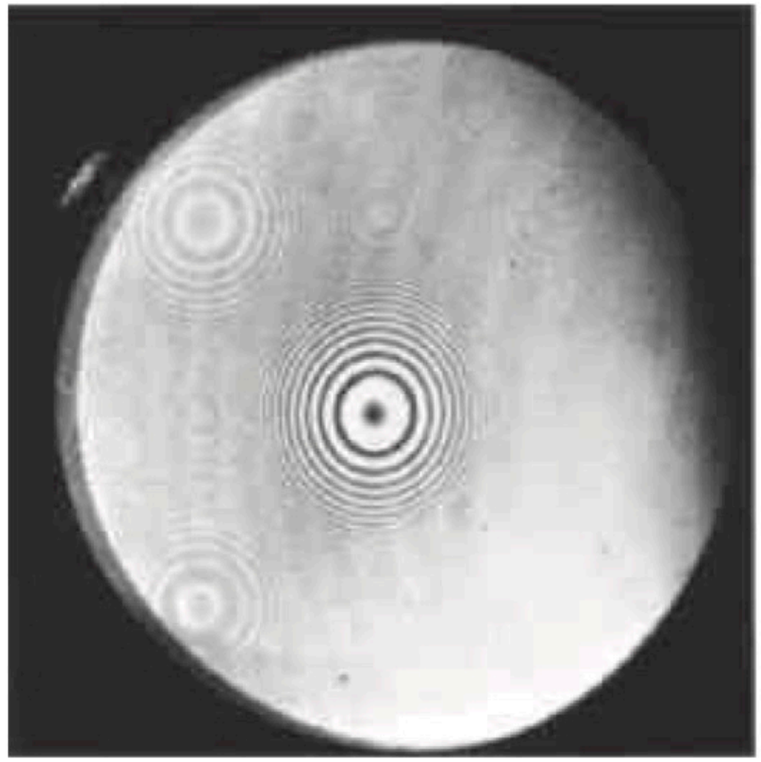


Interference between two glass plates

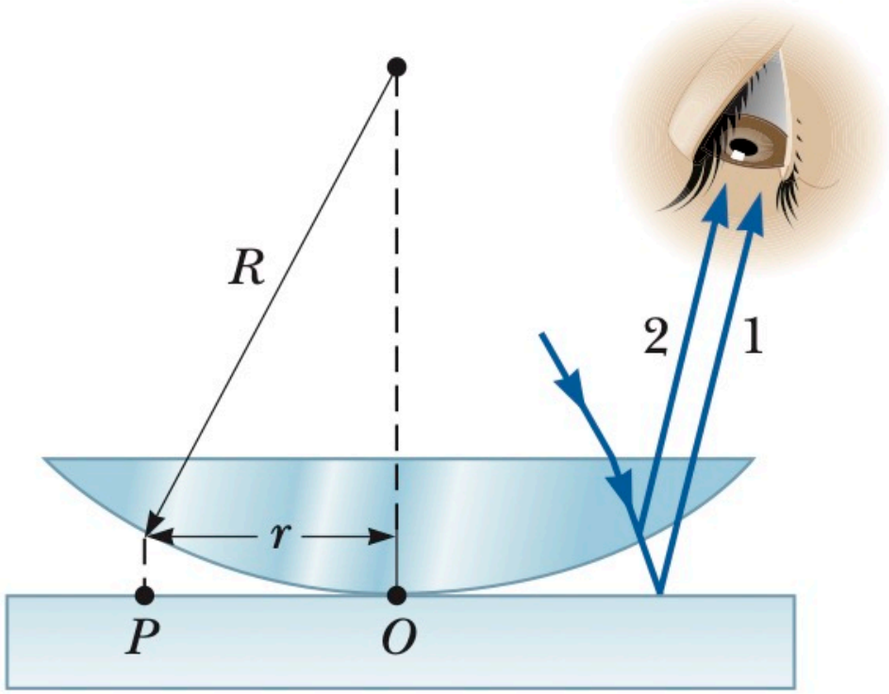
From the two glass plate setup, where does the Interference pattern we see come from?

Newton's rings

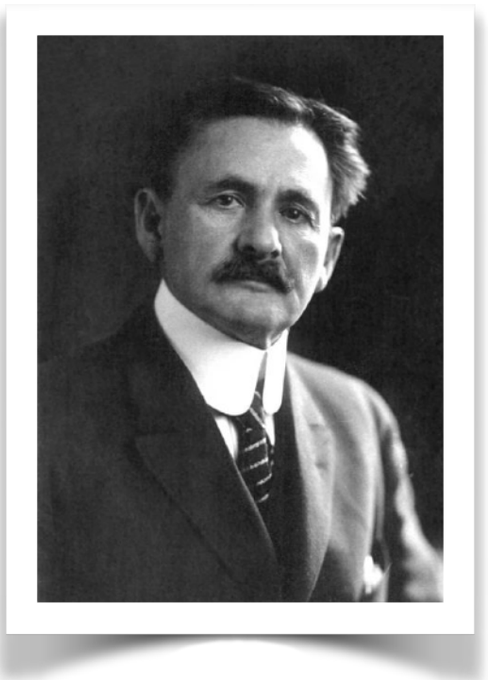
[Wiki] Newton's rings is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces; a spherical surface and an adjacent touching flat surface. It is named after Isaac Newton, who investigated the effect in 1666.



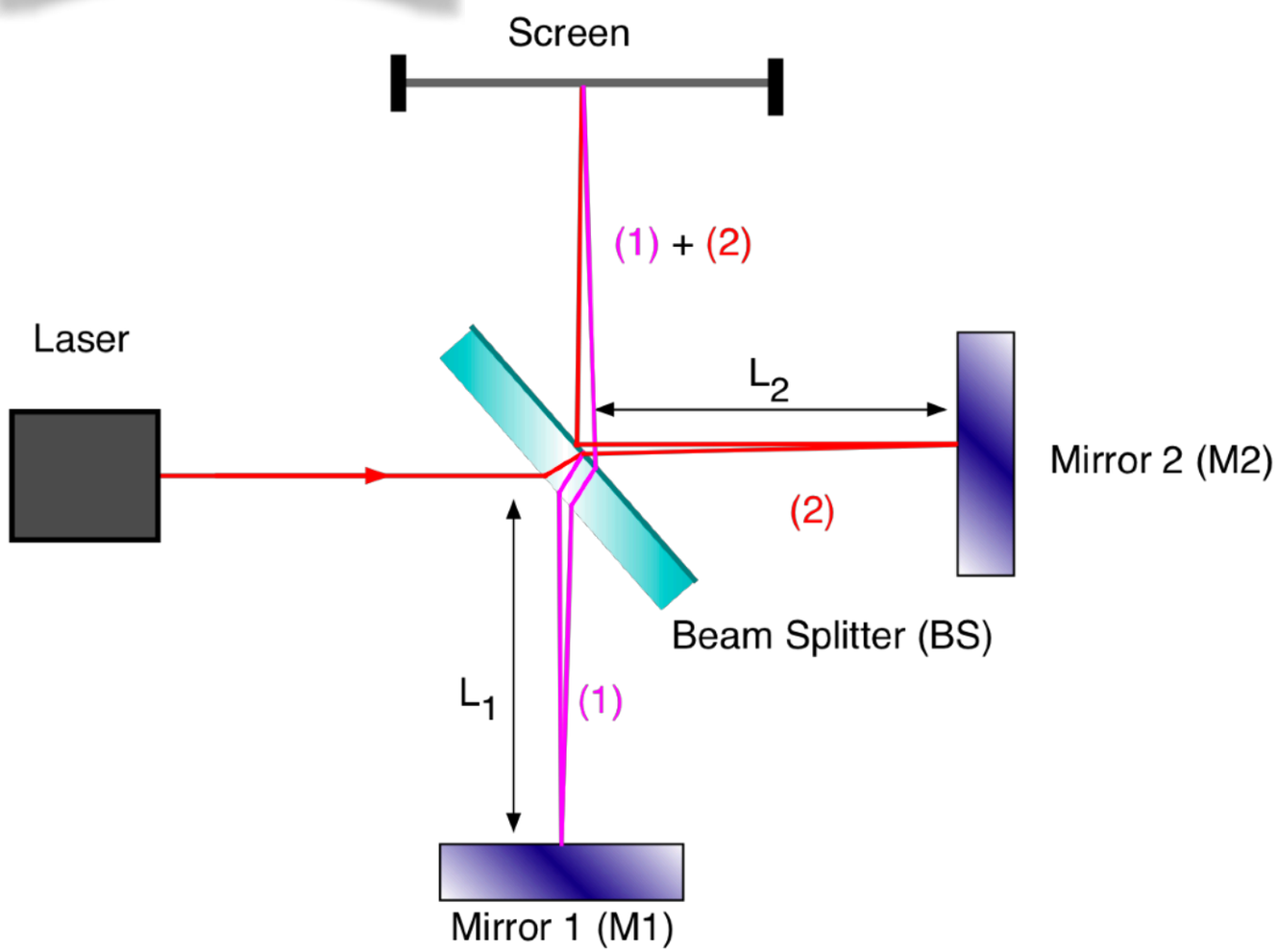
Courtesy of Bausch and Lomb



Michelson interferometer



Albert A. Michelson



A Michelson interferometer is a tool used to produce interference between two beams of light. It works by splitting a beam of monochromatic light into two equal amplitude beams. One beam hits a fixed mirror and the other hits a movable mirror giving different beam lengths which converge on a detector screen giving an interference pattern.

LIGO – A GIGANTIC INTERFEROMETER

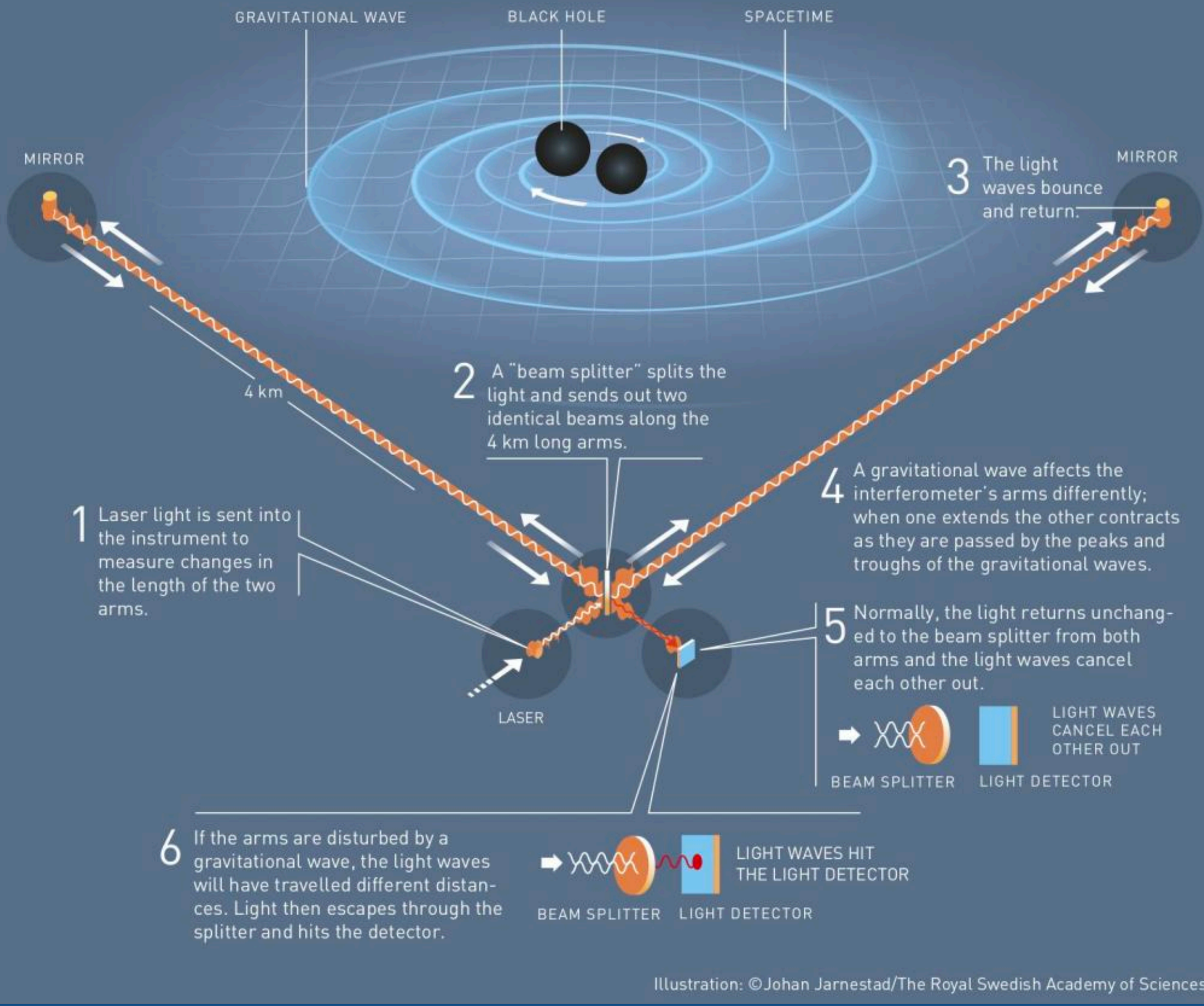


Illustration: © Johan Jarnestad/The Royal Swedish Academy of Sciences