Ch34 – Geometric Optics

Light rays moving in straight lines

Ch35-36 – Wave Optics

Ch35 –Interference

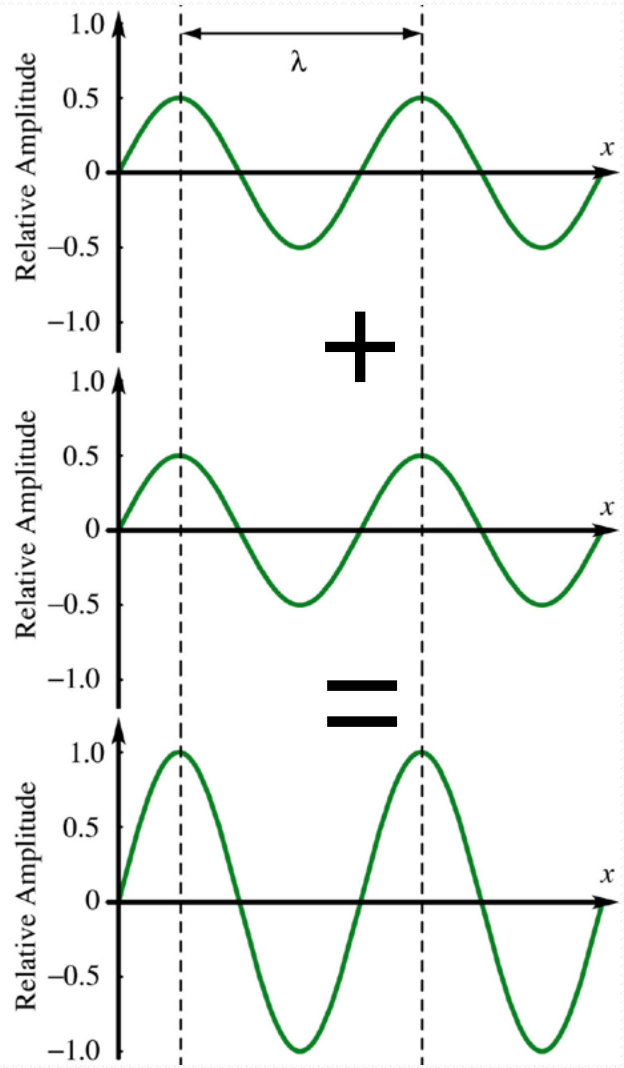
Double-slit

Thin-film

Ch36 – Diffraction

Chapter 35

Interference (refresher)



←← Constructive

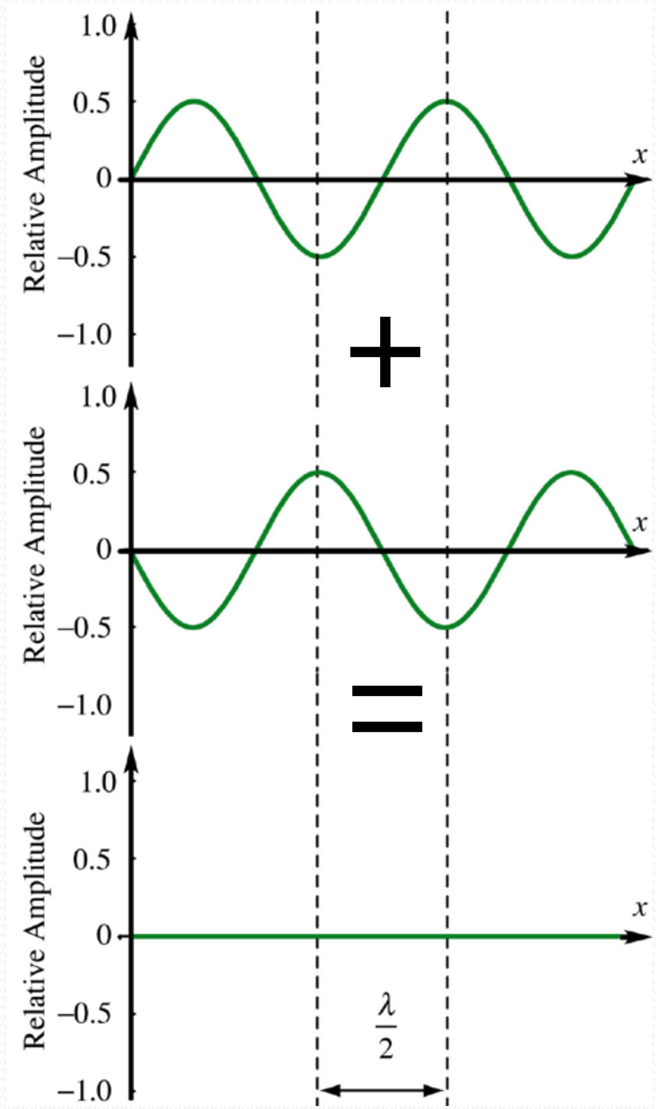
Waves in phase

$\varphi \;\; = 0, 2\pi, \ldots$

Destructive →→

Waves out of phase

$\varphi = \pi, 3\pi \ldots$



Coherent sources

Coherent wave sources = same *frequency* and <u>constant</u> *phase difference*

Constructive

Waves in phase

$\varphi \;\; = 0, 2\pi, \ldots = 2m\pi$

Destructive

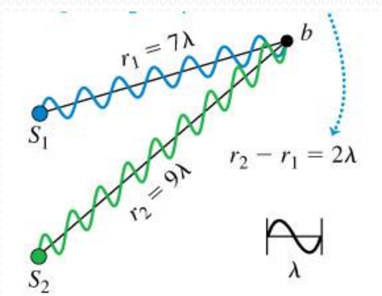
Waves out of phase

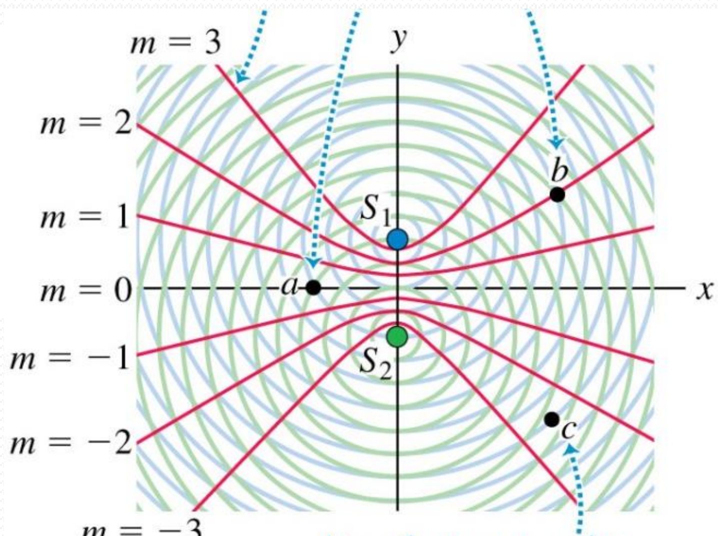
$\varphi = \pi, 3\pi \ldots = (2m+1)\,\pi$

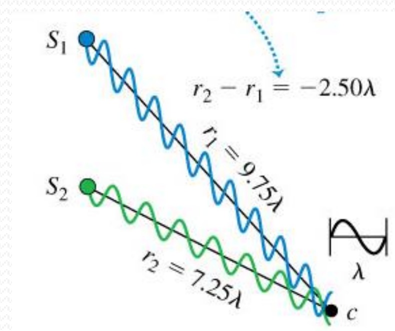
$$\boxed{\frac{\varphi}{2\pi} = \frac{\Delta x}{\lambda}}$$

$\Delta x = m\lambda$

$\Delta x = (2m+1)\frac{\lambda}{2}$







Light Waves

1678 Christiaan Huygens - wave theory of light:

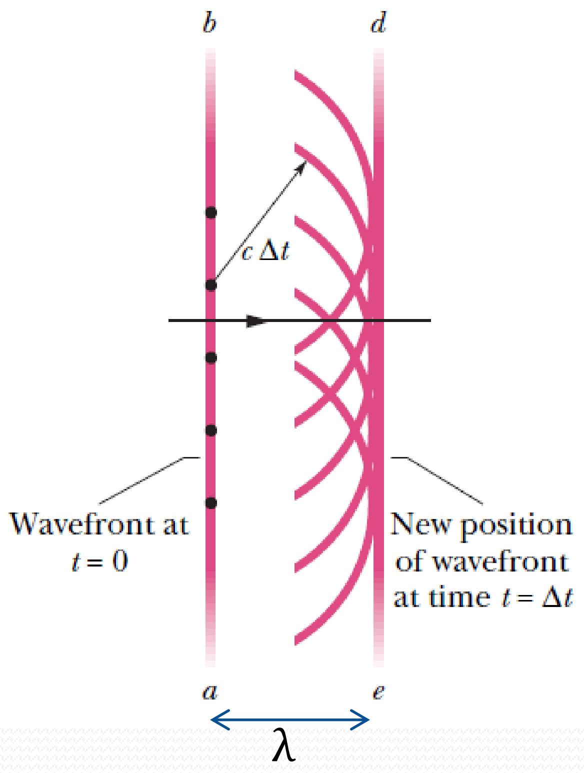
geometrical construction predicting the position of a WF from the present position

1704 Newton – corpuscular hypothesis for light

1873 Maxwell treatise

Reminder:

Wave front – same $\vec{E}(t)$ – are planar *far* from source



Huygens Principle:

All points on a propagating wave front serve as sources of secondary spherical wavelets

After time Δt the new position of the wave front is at a surface tangent to 2nd-ary wavelets

Example: Distance between wave fronts

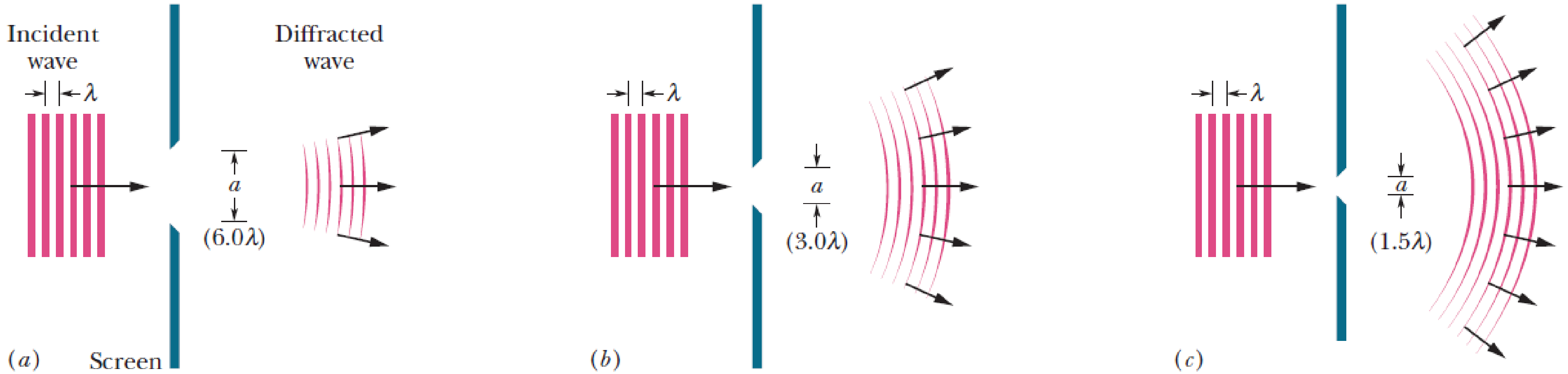
$d = c\,\Delta t$ = radius of wavelets

new WF "ed" ‖ old WF "ab"

$\Delta t \rightarrow T = \frac{1}{f} \qquad \rightarrow \qquad d = c\,T = \frac{c}{f} = \lambda$

Can be used to derive reflection and refraction laws (page 1103)

Diffraction



Diffraction = flaring/spreading of the wave beyond the barrier

Most noticeable when size of opening $a \sim \lambda$

Limits use of geometric optics (straight rays) to scales $\gg \lambda$

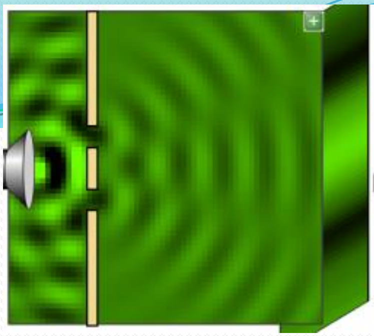
Consequence of Huygens principle

Same effect for barriers (instead of openings)

Same for any type of wave: water, etc.

Chapter 35

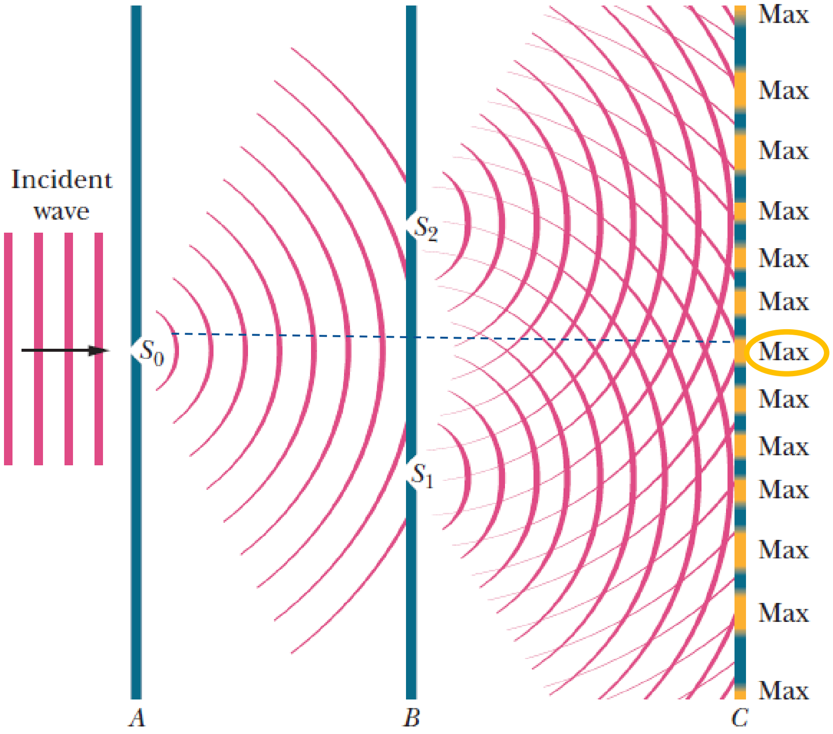
Double-Slit Interference

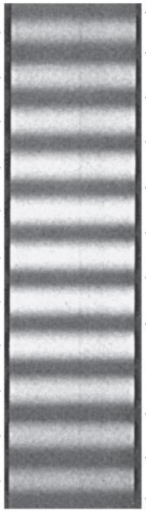


1801 Thomas Young

1. proved light = wave through light interference

2. measured
$\bar{\lambda} = 570nm$ sunlight
(compare to 555 nm → 2.7%)





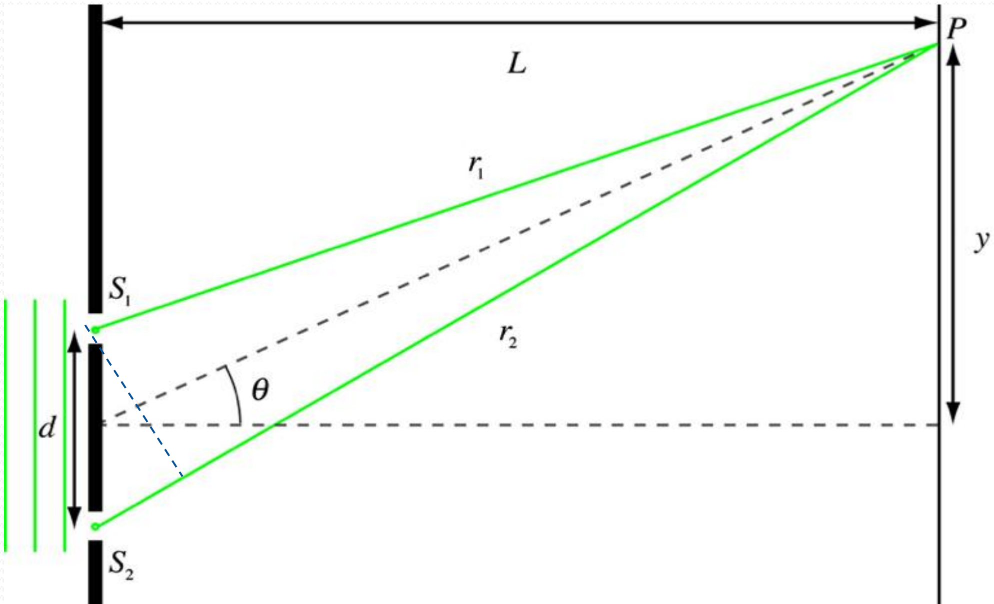
Interference pattern
Bright & dark bands/fringes
Max = middle of bright
Min = middle of dark

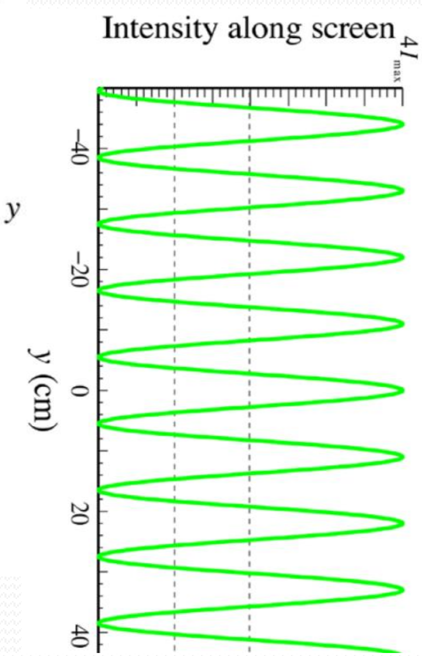
Use Huygens' principle on each slit – followed by *diffraction*

Dynamic view at https://en.wikipedia.org/wiki/Double-slit_experiment

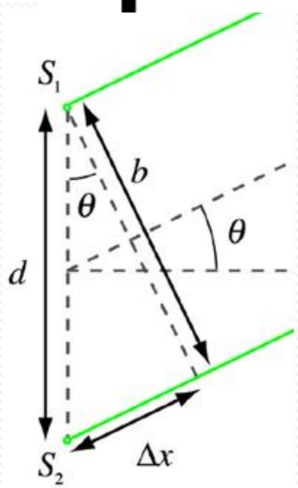
Chapter 35

Double-Slit Interference





$d = 10^{-5} m$
$\lambda = 550\ nm$
$L = 2\ m$



Assume $L \gg d, y$

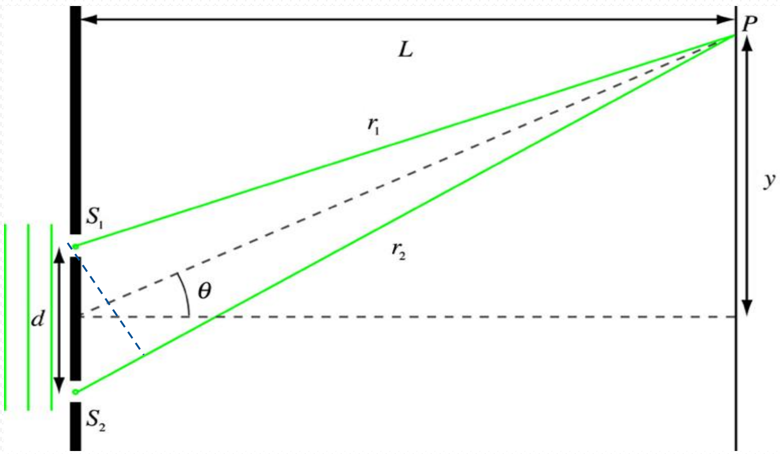
Use SAA $\theta(rad) \approx sin\theta \approx tan\theta$ where θ locates fringes

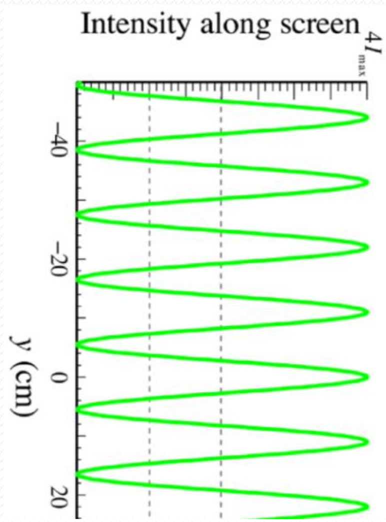
Path ≠ $\Delta x = d\ sin\theta = d\frac{y}{L}$ where $m = 0, \pm 1, \pm 2, \ldots$ labels fringes

Max $\Delta x = d\ sin\theta = m\lambda$ → $y_{max} = m\lambda\frac{L}{d}$

Min $\Delta x = d\ sin\theta = (2m+1)\frac{\lambda}{2}$ → $y_{min} = (2m+1)\ \frac{\lambda}{2}\frac{L}{d}$

Double-Slit Interference





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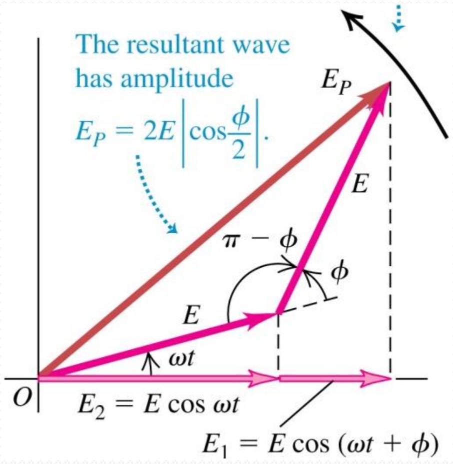


$E_P = 2E\ cos\frac{\varphi}{2}$ resulting amplitude

$$I = S_{ave} = \frac{{E_P}^2}{2\mu_0 c} = \frac{4E^2 cos^2\frac{\varphi}{2}}{2\mu_0 c}$$

$I_0 = \frac{2E^2}{\mu_0 c} = 4\ I_1 = 4\ I_2$ maximum intensity for $\varphi = 0$

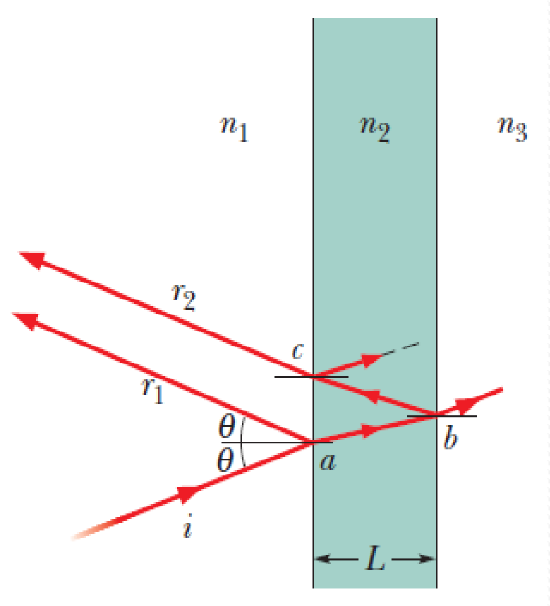
$\boxed{I = I_0\ cos^2\beta}$ where $\beta = \pi\frac{d}{\lambda}sin\theta = \pi\frac{d}{\lambda}\frac{y}{L}$

Chapter 35

Thin-Film Interference

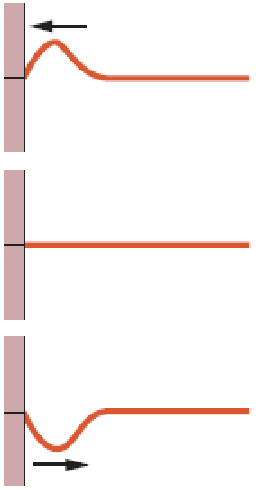
TF = optically clear material with thickness ~ few λ.
e.g. soap bubbles, thin oil on water

TFI = interference of light reflected on front (r_1) and back (r_2)
depends on reflections and path length

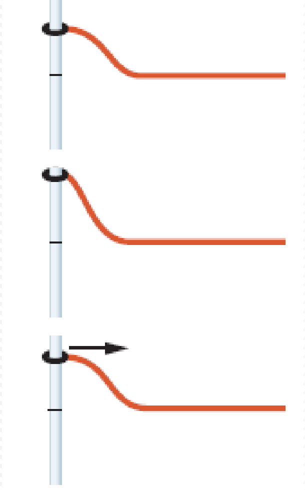


Phase can change at reflection depending on n_1, n_2

"hard" $n_1 < n_2$
$\Delta\varphi = \pi \;\; or \;\; \frac{\lambda}{2}$



"soft" $n_2 > n_3$
$\Delta\varphi = 0$



Thin-Film Interference

Condition	1 Phase shift $(\frac{\lambda}{2})$	0 or 2 phase shifts (λ)
$2L = (2m+1)\frac{\lambda}{2n}$	Constructive	Destructive
$2L = m\frac{\lambda}{n}$	Destructive	Constructive
Example:	Thin film in air	Lens coating

$\mathrm{m} = 0, 1, 2, \ldots$