Physics 262

George Mason University

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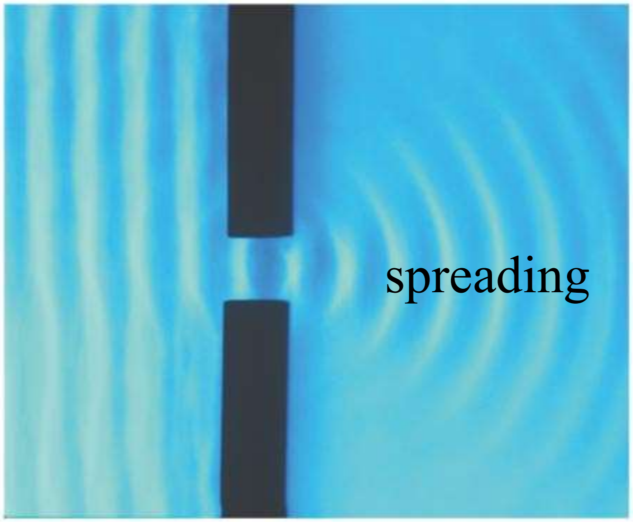
Chapter 35: Interference

- Interference and Coherent Sources
- Two-Source Interference of Light
- Intensity of Interference Patterns
- Interference in Thin Films
- The Michelson Interferometer

Wave Nature of Light

- Previous Chapters (Geometric Optics) $\lambda << L$
  - Rays Model is an approximation of EM waves with rays pointing in the direction of propagation
- Next Couple of Chapters (Wave/Physical Optics) $\lambda \sim L$
  - Like water waves, light *spreads* and *interferes* with each other.
  - Observed phenomena *cannot* be accounted for by rays:

Diffraction

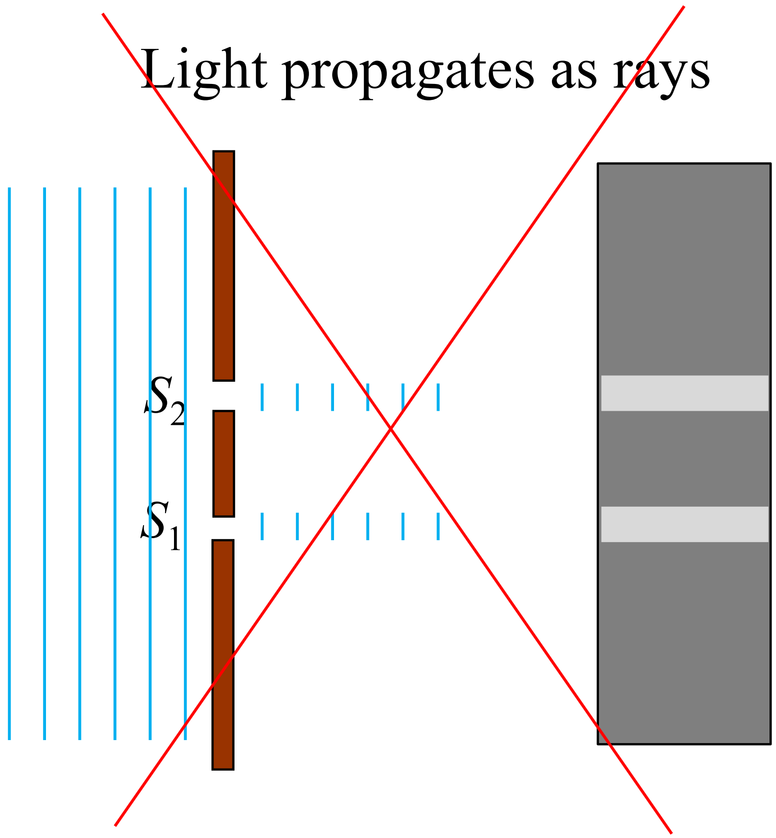


Interference

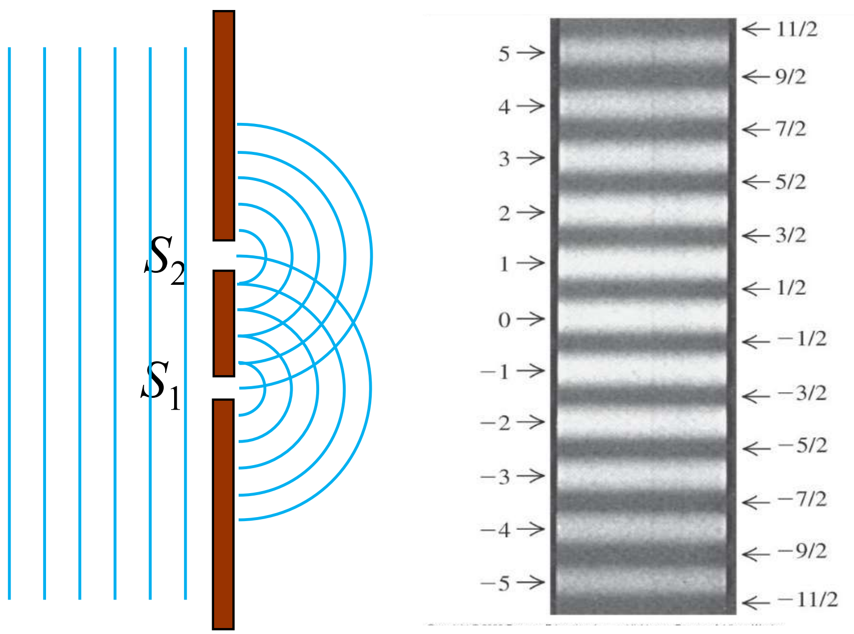
constructive/ destructive interference patterns

Wave Nature of Light: Diffraction & Interference

Light propagates as rays

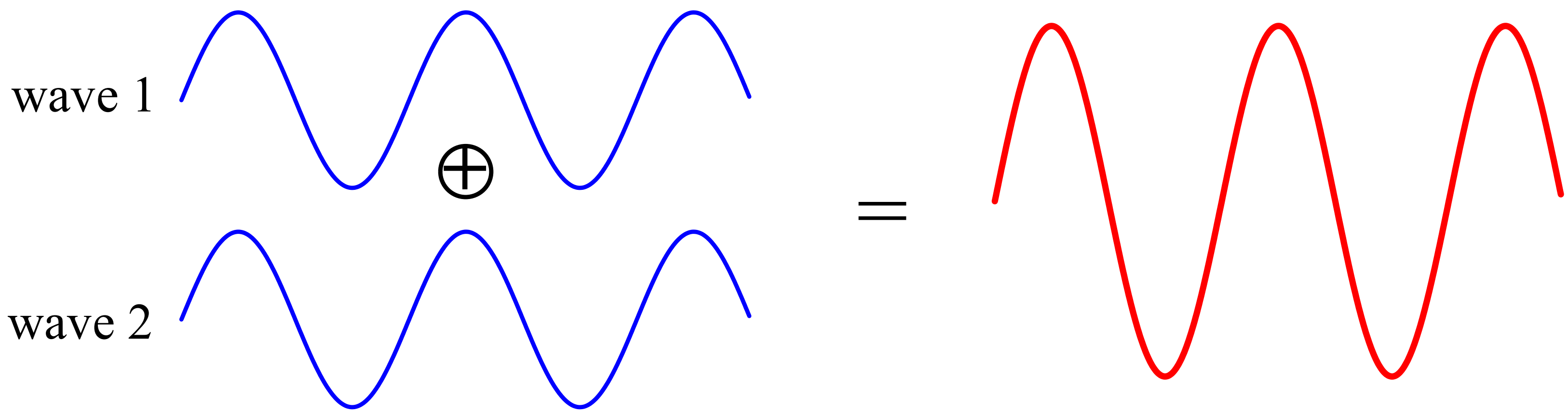


Light propagates as waves

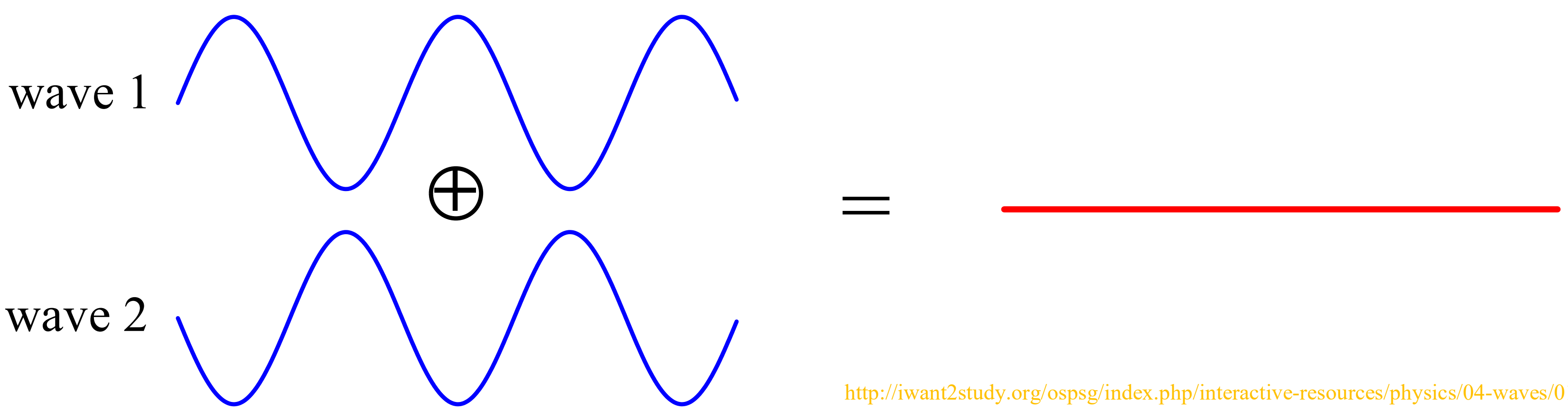


Interference and Superposition

Constructive Interference (+ peaks aligns w/ + peaks)



Destructive Interference (+ peaks aligns w/ - peaks: $\lambda/2$ apart)

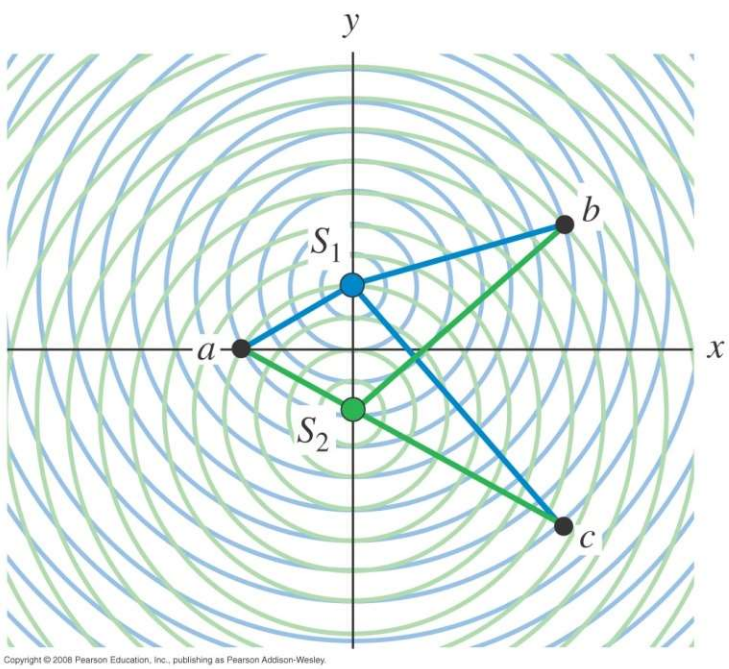


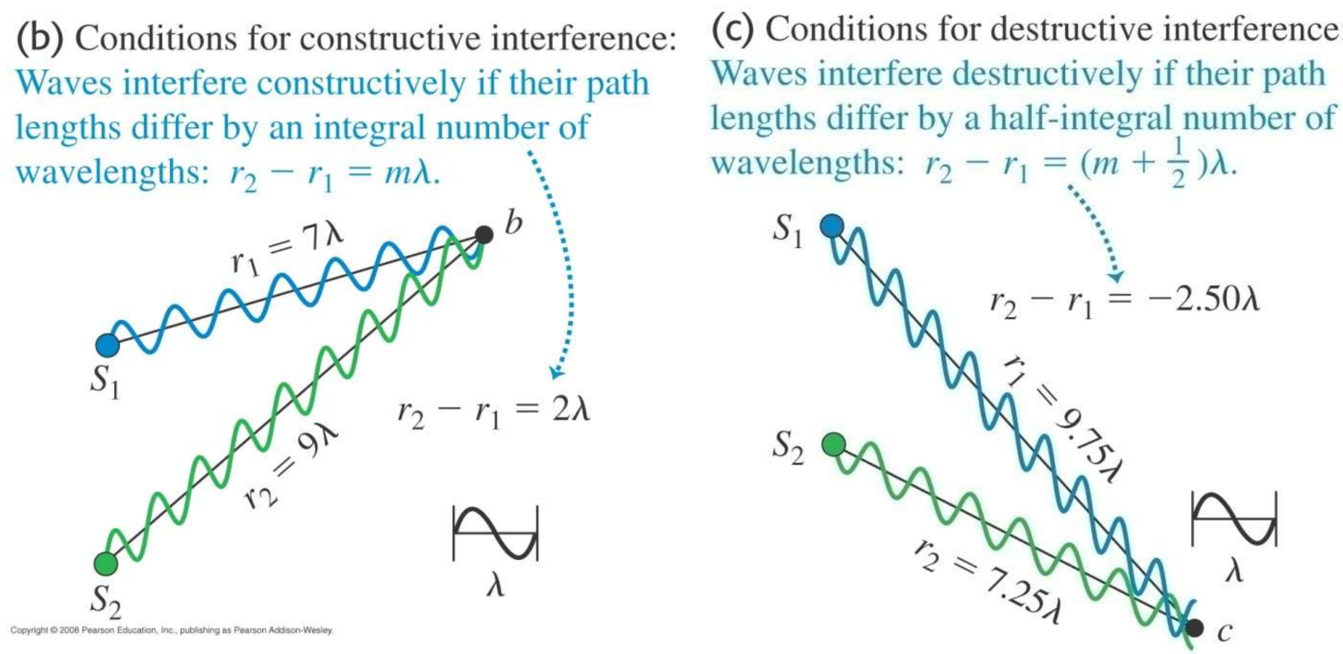
http://iwant2study.org/ospsg/index.php/interactive-resources/physics/04-waves/01-superposition/384-wave1d01

Interference, Superposition, & Path Difference

(a) Point *a* is symmetric with respect to the two coherent sources. Waves will arrive in phase *constructively*: r_2 - r_1 = 0.

$D_{\text{two sheets}}$





r_1 : distance to S_1

r_2 : distance to S_2

$r_2 - r_1 =$ **path difference**

Constructive Inter.

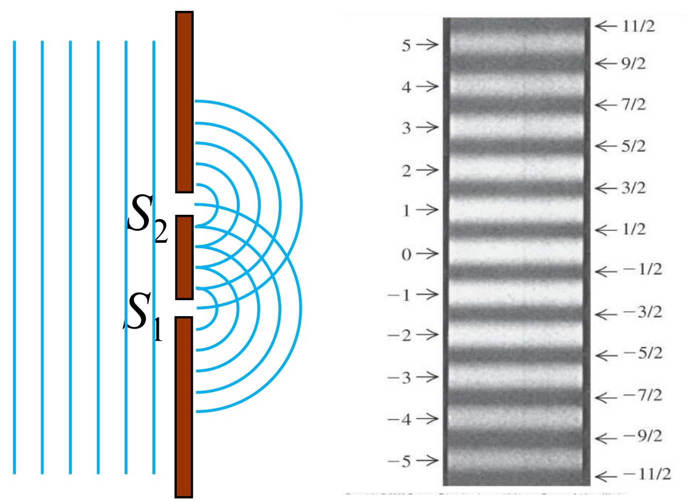
$$r_2 - r_1 = m\lambda$$
$$(m = 0, \pm 1, \pm 2, \cdots)$$

Destructive Inter.

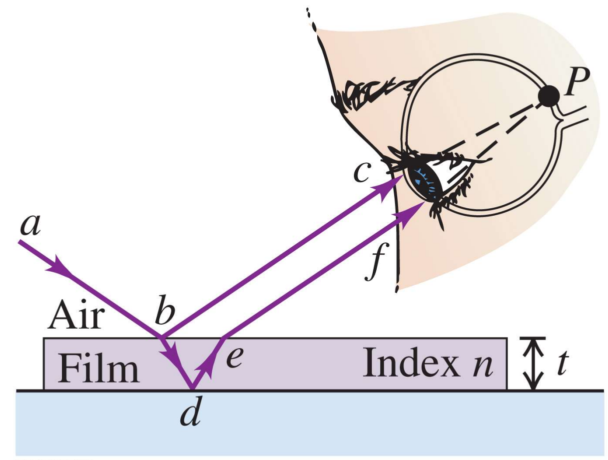
$$r_2 - r_1 = \left(m + \frac{1}{2}\right)\lambda$$
$$(m = 0, \pm 1, \pm 2, \cdots)$$

Many Ways when Waves can Interfere

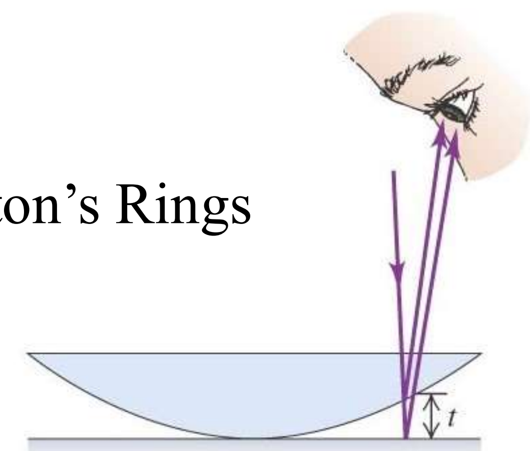
Young's Double Slits



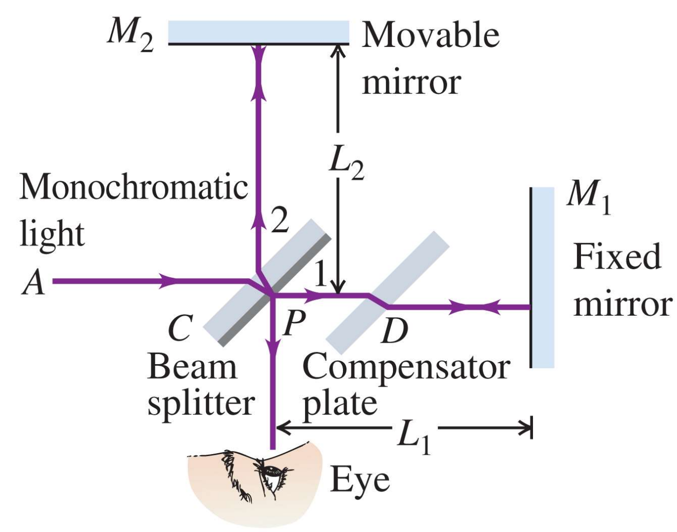
Diff Thin Film Scenarios



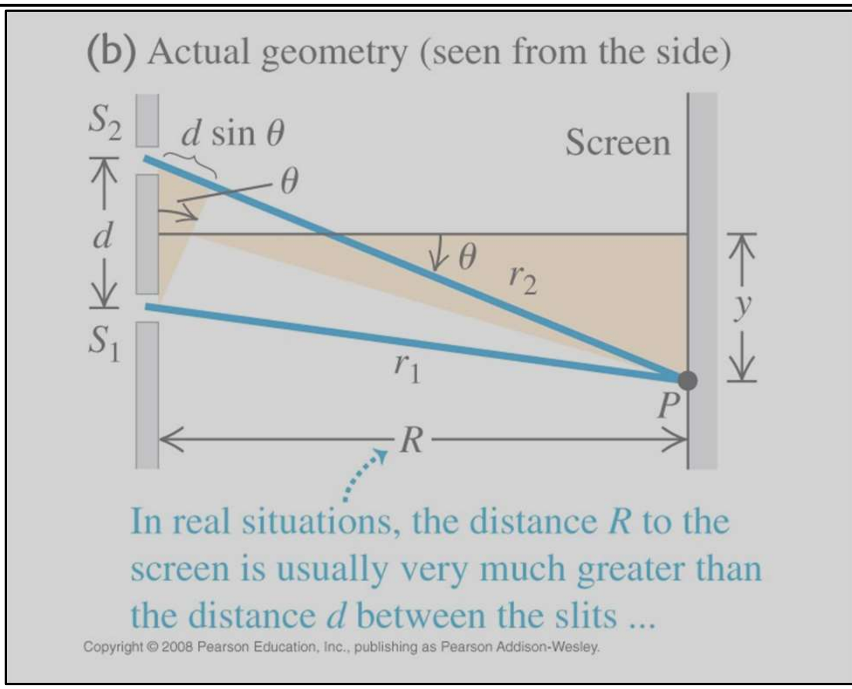
Newton's Rings

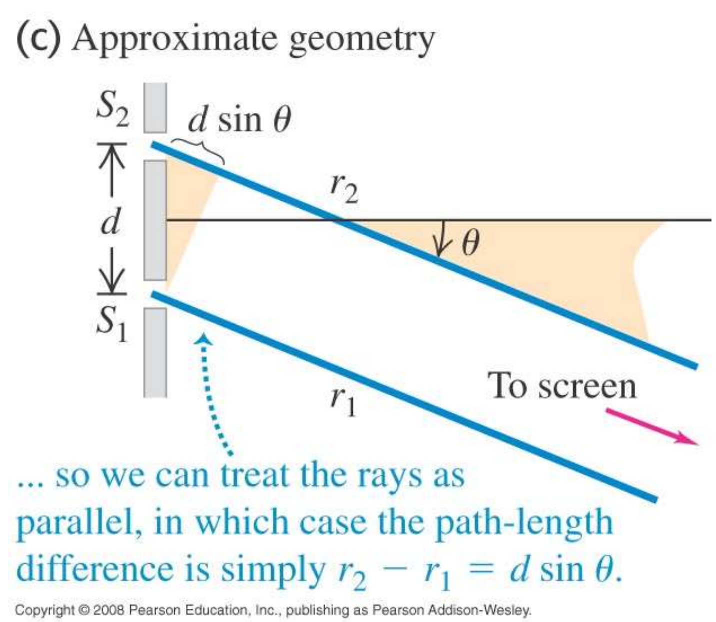


Michelson Interferometer



Young's Double-Slit





If screen is far away so that $R >> d$, we can assume rays from S_1 and S_2 to be approximately parallel.

Then, from the simplified geometry (right panel), we have an explicit expression for the **path difference**:

$$r_2 - r_1 = d \sin \theta$$

(θ is the angular location of observation point P on the screen.)

Constructive/Destructive Young's Double-Slit Interference

For observing distance $R >> d$, we have the following conditions:

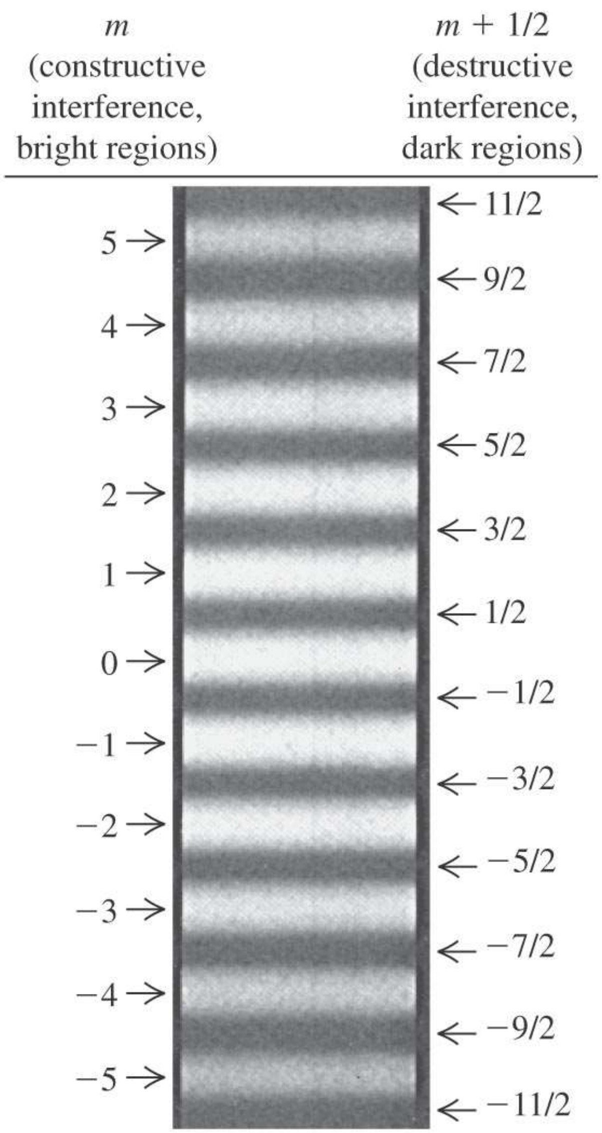
Constructive Interference: Two Slit Interference

$$d \sin\theta = m\lambda \quad (m = 0, \pm 1, \pm 2, \cdots)$$

Destructive Interference: Two Slit Interference

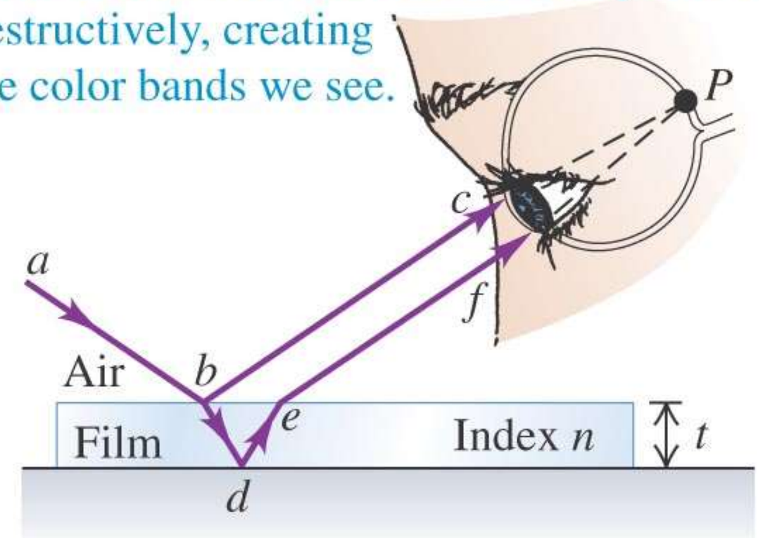
$$d \sin\theta = \left(m + \frac{1}{2}\right)\lambda \quad (m = 0, \pm 1, \pm 2, \cdots)$$

- The bright/dark bands in the pattern are called fringes
- m is the *order* of the fringes



Interference in Thin Films

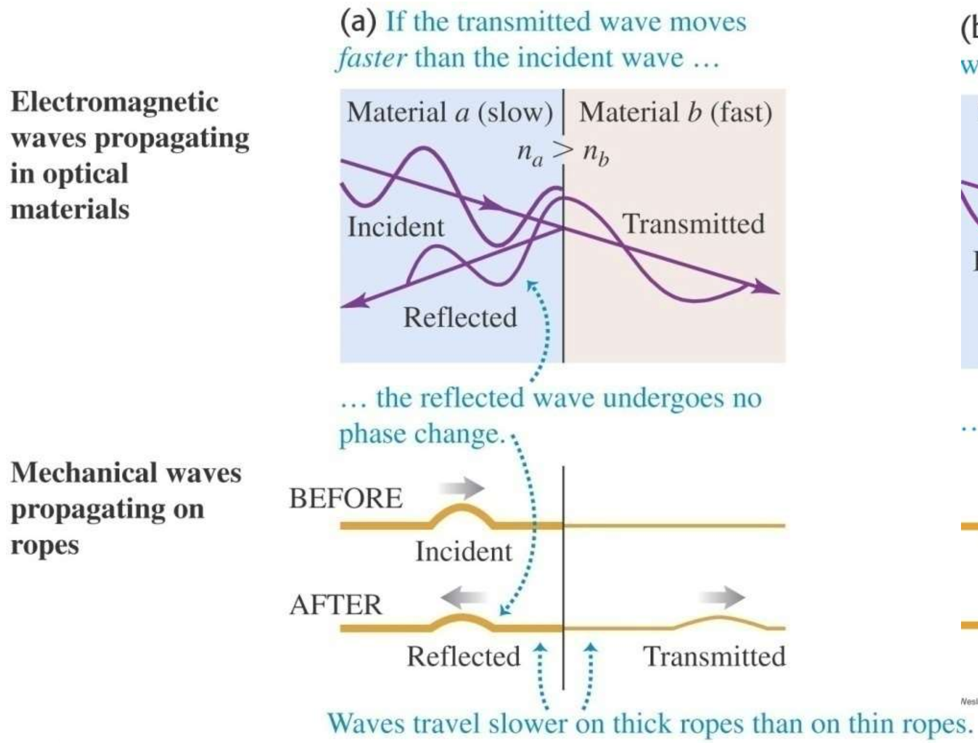
Color fringes observed from an oil slick on water or on a soap bubble are the white-light *interference* patterns produced by the *reflected* light off a *thin film* of oil or soap.



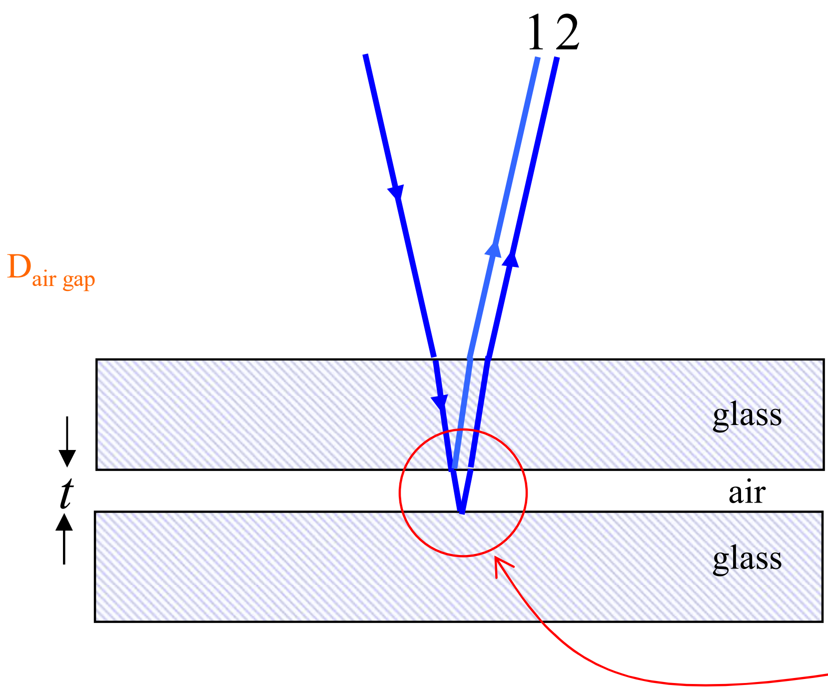
Phase Reversal upon Reflection

From Maxwell's Equations, one can show that the reflected wave will suffer a 180° or $\lambda/2$ phase shift if it is reflected off from a medium with a *larger n*.

$$E_r = \frac{n_a - n_b}{n_a + n_b} E_i \qquad \text{(for normal incidence)}$$



Interference from a Thin Air Gap



Assumptions:

- Thickness of air gap *t* is small
- Thickness of glass is large
- Incident light is nearly *normal* at the upper plate.

Interference due to this small gap

NOTE: While wave #2 suffers a phase reversal upon reflection at the bottom or the gap, wave #1 did not.

Interference from a Thin Air Gap

Condition for Constructive and Destructive from thin film when one of the waves suffers a phase reversal upon reflection

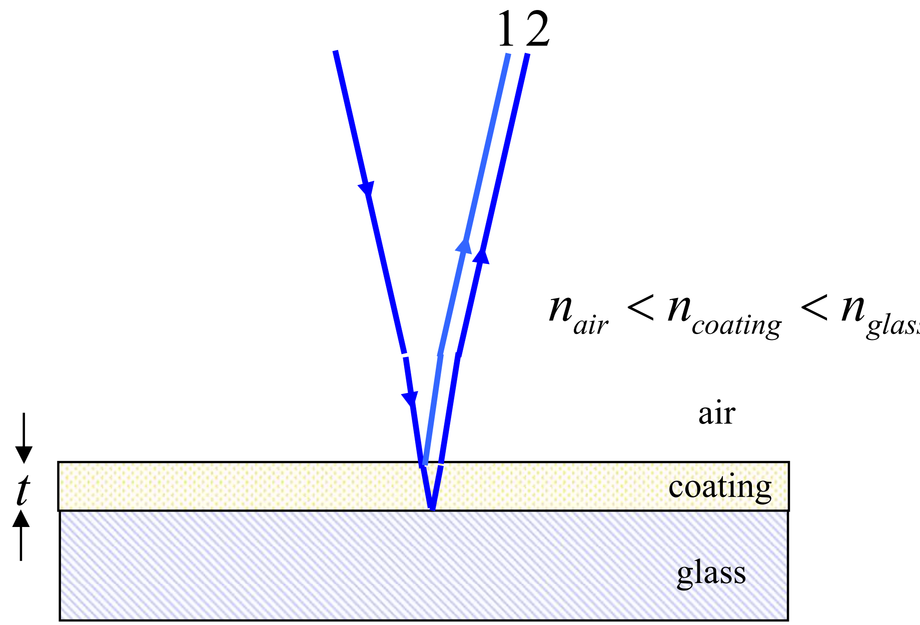
Constructive: $$2t = \left(m + \frac{1}{2}\right)\lambda, \quad m = 0, 1, 2, \cdots$$

Note that we need to take the extra "sign change" or half a wave ($\lambda/2$) into account on the right-hand side

Destructive: $$2t = m\lambda, \quad m = 0, 1, 2, \cdots$$

→ the switched condition on the right-hand side !

Another Thin Film Example (non-refractive coating on lens)



wave #1: reflected from top interface of the coating:

$$n_{air} < n_{coating} \quad \Rightarrow \quad 180^{o} \text{ (or } \pi \text{) phase reversal}$$

wave #2: reflected from bottom interface of the coating:

$$n_{coating} < n_{glass} \quad \Rightarrow \quad 180^{o} \text{ (or } \pi \text{) phase reversal}$$

Interference from a Thin Film

Condition for Constructive and Destructive from thin film when both waves suffers a phase reversal upon reflection (NO net sign change)

Constructive:

$$2t = m\lambda_n, \quad m = 0, 1, 2, \cdots$$

$$2n_{coating}t = m\lambda, \quad m = 0, 1, 2, \cdots$$

Destructive:

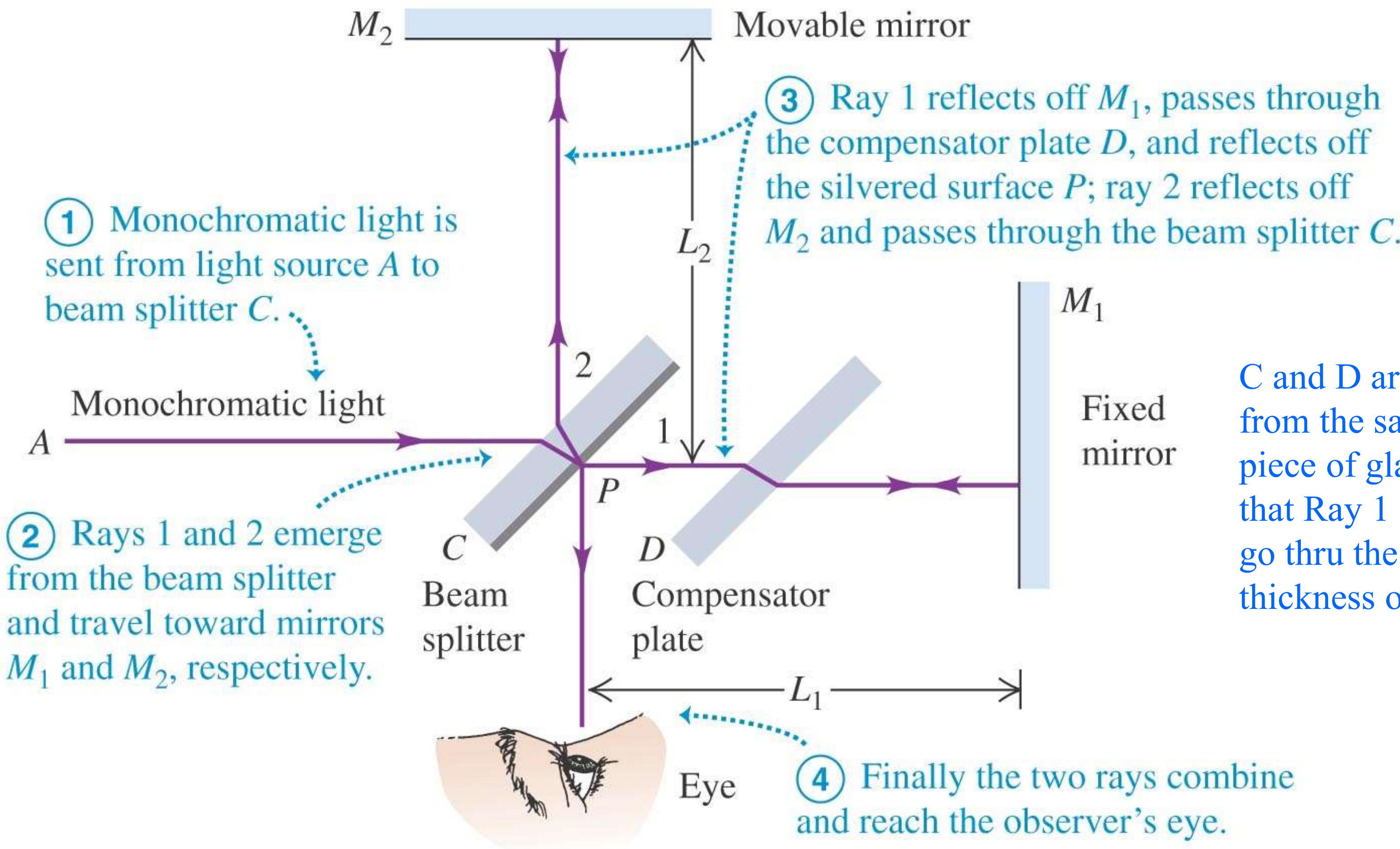
$$2t = \left(m + \frac{1}{2}\right)\lambda_n, \quad m = 0, 1, 2, \cdots$$

$$2n_{coating}t = \left(m + \frac{1}{2}\right)\lambda, \quad m = 0, 1, 2, \cdots$$

Since reflection occurs inside a medium with n, wavelength is shorter

$$\lambda_n = \frac{\lambda}{n}$$

Michelson Interferometer



C and D are cut from the same piece of glass so that Ray 1 & 2 will go thru the same thickness of glass.

Distances comparable to λ can be measured with ease using this device by counting fringes.