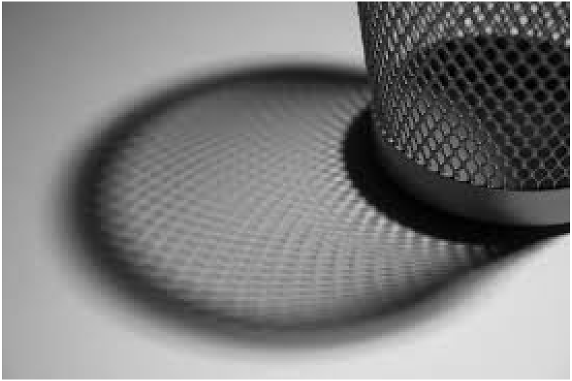
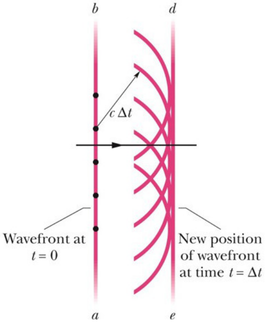
Chapter 3 - Interference



David J. Starling
Penn State Hazleton
PHYS 214

Light as a Wave

Given that light is an electromagnetic wave, we describe its propagation using waves.



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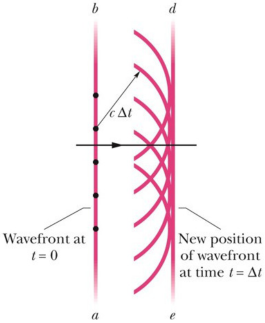
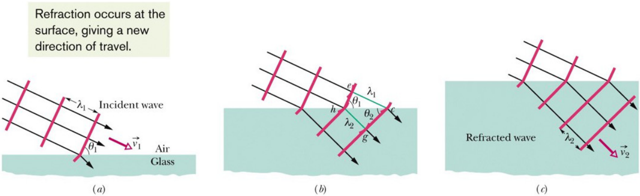


Every point on the wavefront propagates outward isotropically.

Light as a Wave

When light meets an interface, it bends according to the same principle.



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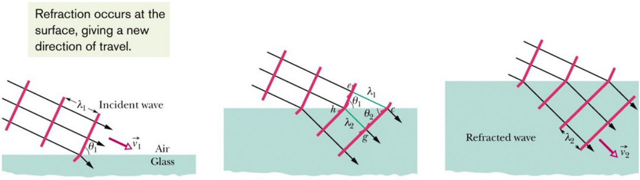

(a) (b) (c)

Light travels slower in glass/water and the wavelength shrinks. This bending is known as **refraction**.

Light as a Wave

The index of refraction n is the reduction factor in the speed of light:

$$v = \frac{c}{n} \tag{1}$$

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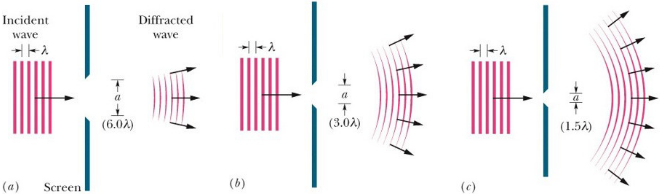
Since the light did not lose energy, its frequency remains the same.

- $v = \lambda f$
- Therefore, as v drops, λ drops
- $\lambda_n = \lambda / n$

Young's Interference

When monochromatic light intersects a narrow slit, the light flares (consistent with Huygen's principle).



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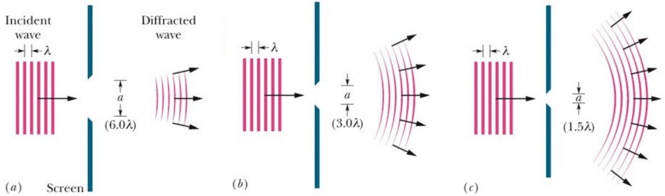
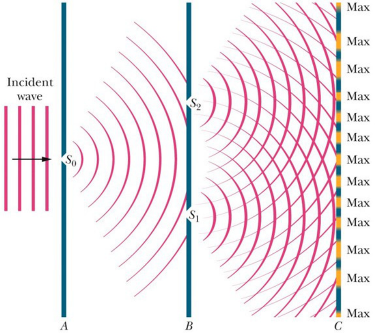
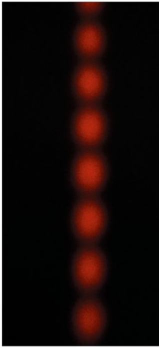


This effect is known as diffraction and is true for all waves.

Young’s Interference

When monochromatic light intersects two narrow slits, the light from each slit can **interfere**.





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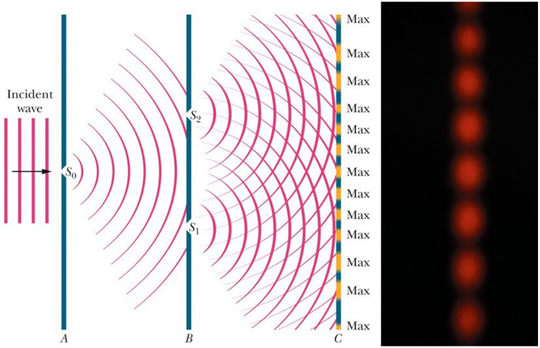


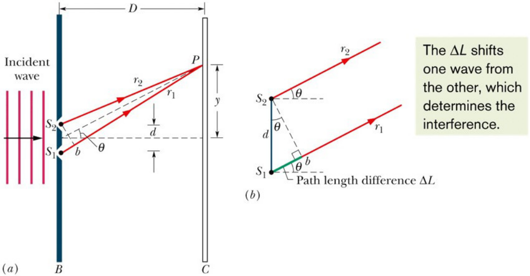
This interference is the result of the EM oscillations adding constructively and destructively.

Young's Interference

For slits separated by a distance d and a screen $D \gg d$ away, the maxima and minima are located at:

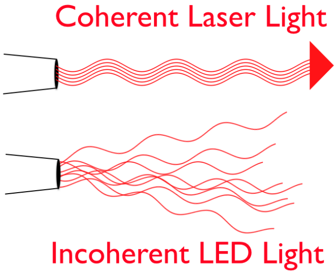
$$d \sin(\theta) = m\lambda \qquad (2)$$

$$d \sin(\theta) = (m + 1/2)\lambda \qquad (3)$$



Young's Interference

In order to obtain good visibility for the maxima and minima, the light must be monochromatic and coherent.



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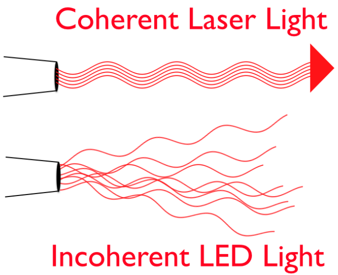
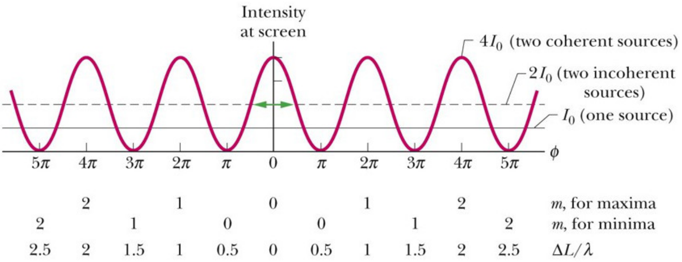


For incoherent light (LEDs, sunlight, room lights), the waves do not add in a sensible way.

Young's Interference

For a fixed point on the screen, the intensity can exceed its incoherent maximum.



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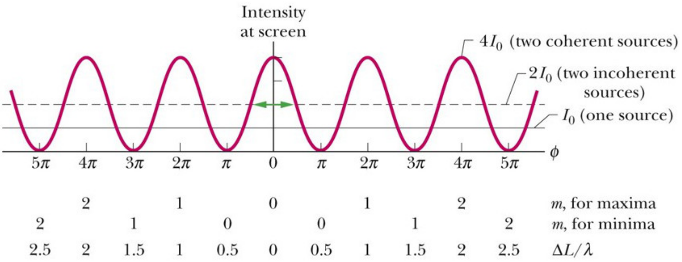


The electric fields add and intensity $I \propto E^2$.

Young's Interference

Lecture Question 3.1

Which of the following must be satisfied if interference is to occur for light passing though a single slit?

(a) The light source must be a point source.

(b) The light must be traveling with an angle of incidence of 0° toward the slit.

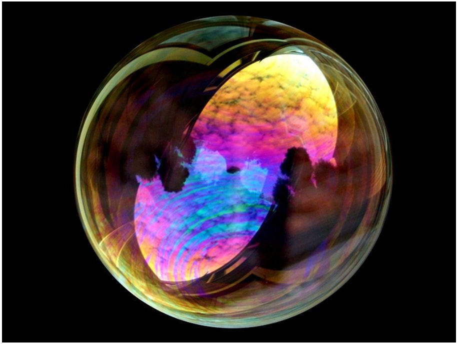
(c) The distance from the slit to the observation screen must be greater than the width of the slit.

(d) The width of the slit must be comparable to the wavelength of light.

(e) The light must be comprised of a single wavelength.

Thin Films

When light is incident on any material, there is some probability for it to reflect, transmit or get absorbed.



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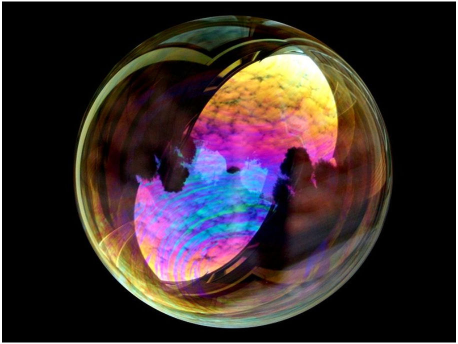
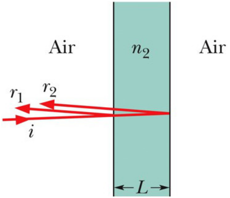


If the material is thin, interference can be observed from multiple reflections.

Thin Films

Light reflected from the front and the back surfaces of a thin film can interfere.



$$2L = (m + 1/2)\frac{\lambda}{n_2} \quad \text{(reflective)} \tag{4}$$

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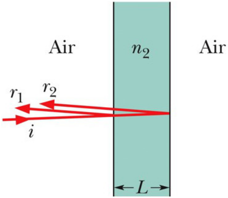

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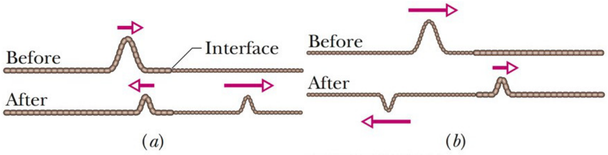
Interferometers

When light reflects off of a surface, the phase of the light can be shifted based upon the index if refractions involved.



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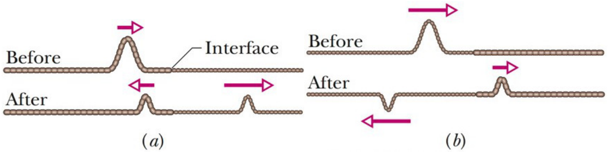
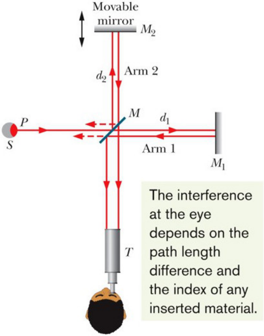


If reflecting off lower index, no phase change; off higher index, 1/2 wavelength shift.

Interferometers

An interferometer separates and combines coherent light in order to measure small length changes using interferences.



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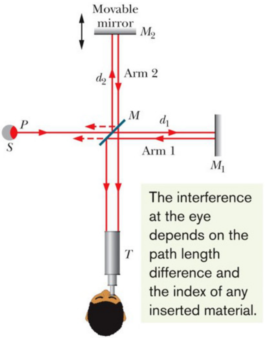

Each path accumulates its own phase. The difference determines the output intensity: $\phi = 2L/\lambda$.

Interferometers

Lecture Question 3.2

A variable wavelength laser can produce light between 400 nm and 700 nm with constant intensity. This light is directed at a thin glass film ($n = 1.53$) with a thickness of 350 nm, surrounded by air. As you scan through these possible wavelengths, which wavelength of light **reflected** from the glass film will appear to be the brightest, if any?

(a) 428 nm

(b) 535 nm

(c) 657 nm

(d) 700 nm

(e) Since the intensity of the light is constant, all wavelengths of light reflected from the glass will appear to be the same.