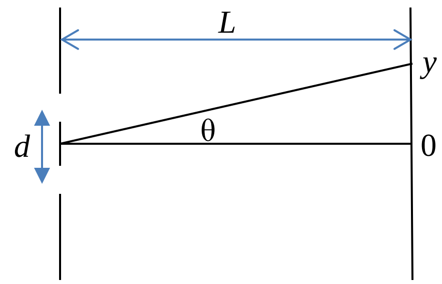
Part 2: Physical Optics

2.1. Interference

<u>Young's Double Slit</u>



$$d \sin\theta = \begin{cases} m\lambda & \text{maxima} \\ (m+1/2)\lambda & \text{minima} \end{cases}$$

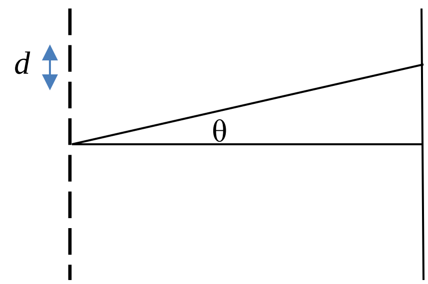
and if $L >> d$

$$y = \begin{cases} m\,\lambda L/d & \text{maxima} \\ (m+1/2)\,\lambda L/d & \text{minima} \end{cases}$$

where $m = 0, \pm1, \pm2, \ldots$

Spacing between consecutive maxima = Spacing between consecutive minima = $\Delta y = \lambda L / d$

<u>Diffraction Grating</u>



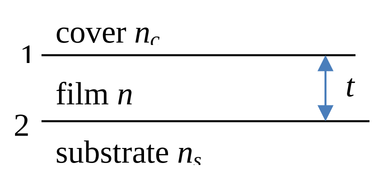
Grating Equation

$$d \sin\theta = m\lambda$$

where <u>order number</u> $m = 0, \pm1, \pm2, \ldots$

The <u>grating constant</u> is the reciprocal of the line spacing d. [# lines / length]

<u>Thin Films</u>



If reflection is lo n off of hi n, then phase shift is π.
If reflection is hi n off of lo n, then phase shift is 0.

Find phase shifts for surfaces 1 and 2. Subtract the two phase shifts to get Δφ.

For near-normal incidence,

	$\Delta\varphi = 0$	$\Delta\varphi = \pi$
$2nt = m\lambda_o$	maxima	minima
$2nt = (m+1/2)\lambda_o$	minima	maxima

Example:
A lens with an index of 1.5 has an anti-reflection coating with an index of 1.4 that minimizes the reflection of 580 nm-light. (a) What is the thinnest that this layer can be? (b) What is the longest wavelength that is strongly reflected?

Ans. (a) 103.6 nm (b) 290 nm so the transmission is enhnaced for all visible light

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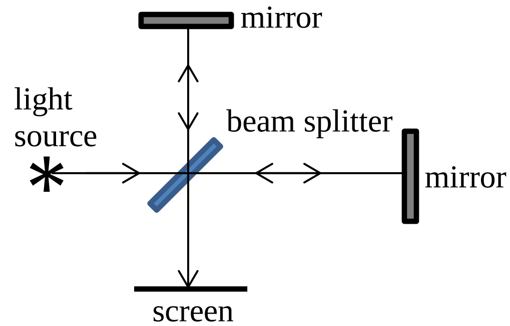
<u>Michelson Interferometer</u>

Move mirror distance *d*. Count *N* fringe shifts on screen.
(A fringe shift is max-to-min-to max.)

$$d = \frac{N\lambda}{2}$$



2.2. Diffraction

<u>Single Slit</u>

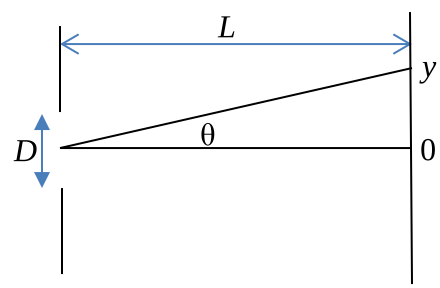
Intensity <u>minima</u> given by

$$D \sin\theta = m\lambda$$

and if $L >> D$

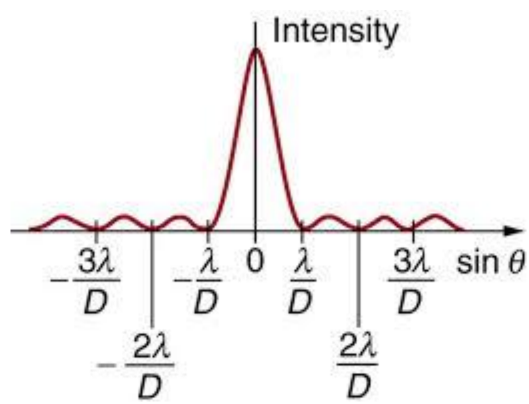
$$y = m\,\lambda L/D$$

where $m = \pm1, \pm2, \ldots$



Width of central diffraction peak (CDP)

$$W_{CDP} = 2\,\lambda L/D$$



Circular Aperture

First minimum given by

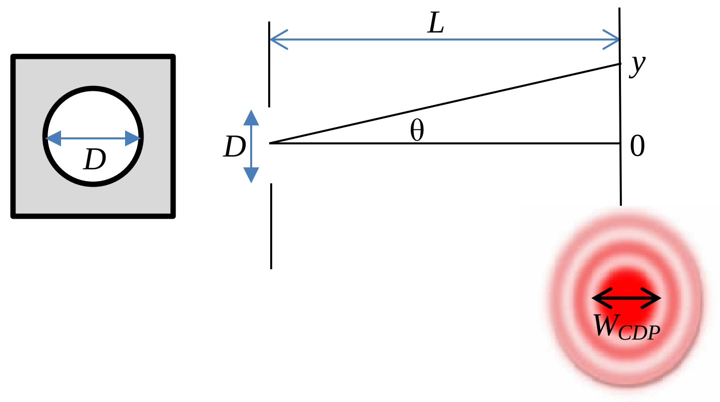
$$D \sin\theta_1 = 1.22\lambda$$

and if $L >> D$

$$y = 1.22\,\lambda L/D$$

Diameter of Airy disk (CDP)

$$W_{CDP} = 2.44\,\lambda L/D$$

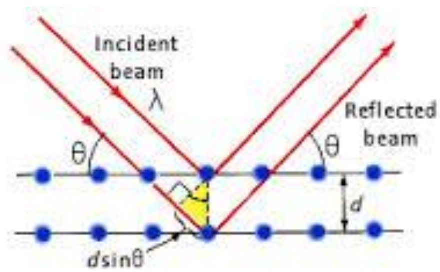


X-Ray Diffraction

Strong reflection if

$$2d \sin\theta = m\lambda$$

where $m = 1, 2, \ldots$



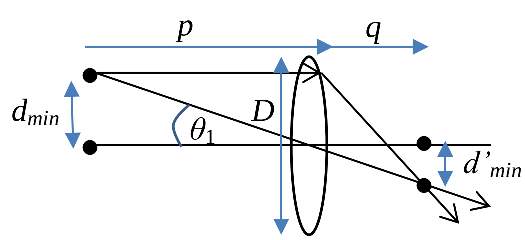
Diffraction-Limited Resolution

Two points on the object are just resolvable as two distinct points on the image when

$$D \sin\theta_1 = 1.22\lambda$$

The angle θ_1 is the resolution angle and since it is very small, $\sin\theta_1 \sim \theta_1$ so the above equation can be written as

$$\theta_1 = \frac{1.22\lambda}{D} \quad \text{[rads]}$$



The minimum separations of these two points on the object and image are given by

$$\theta_1[\text{rads}] = \frac{d_{min}}{p} = \frac{d'_{min}}{q}$$

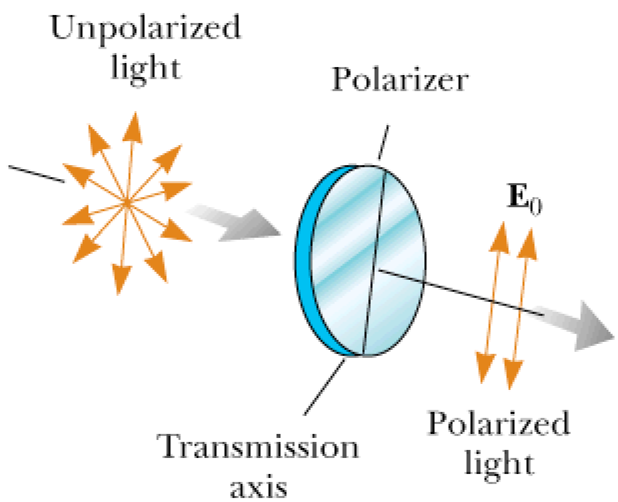
Useful angle conversions: π rad = 180°
1° = 60'= 60'
1 arcminute = 60 arcseconds = 60"

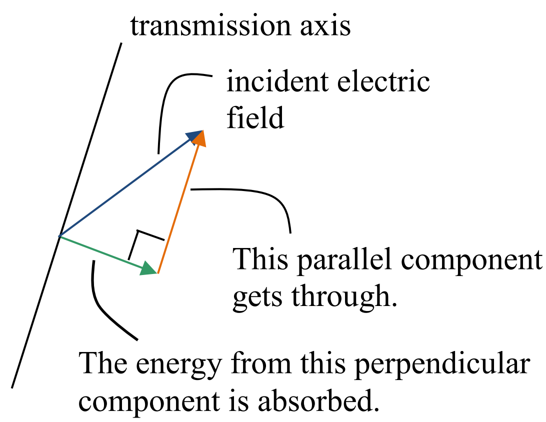
Example:
The pupil of a person's eye is opened to a diameter of 2 mm. Find (a), the resolution angle of this eye, and (b), the closest that two points can be separated by on the page of a book that is 25 cm from the eye. Use a free-space wavelength of 560 nm which is in the middle of the visible spectrum. (c) These two points are imaged on the retina which is 20 mm from the pupil. How close are the two imaged points on the retina?

Ans. (a) 2.57×10^{-4} rad = 53" (b) 64 μm (c) 5 μm

2.3 Polarization

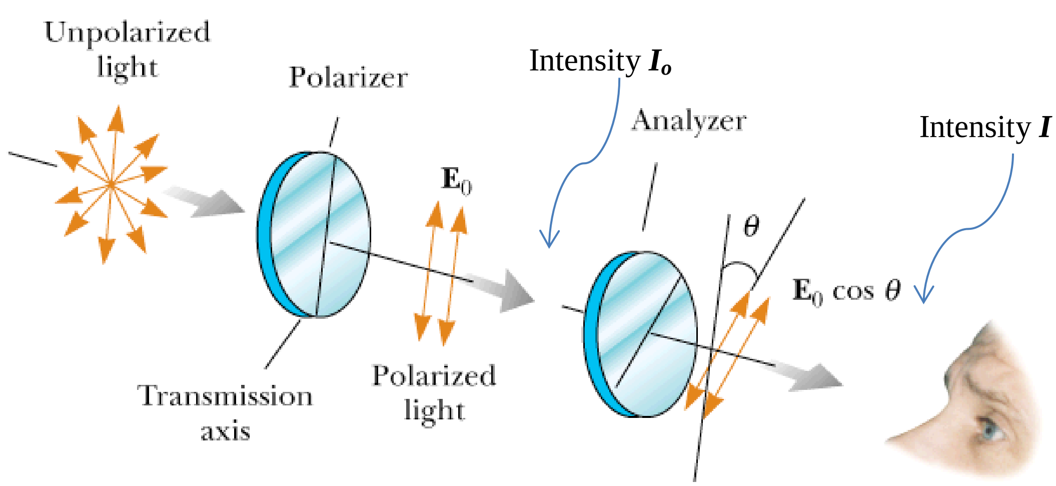
Linear Polarization of Light by Linear Polarizer





Law of Malus

$$I = I_o \cos^2\theta$$

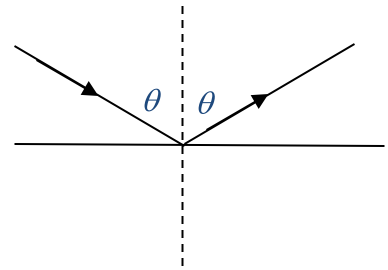


Linear Polarization by Reflection (Brewster's Law)

As the incident angle θ gets closer to the polarization angle (Brewster angle) θ_P, more of the reflected light is linearly polarized with the electric field axis parallel to the surface.

When $\theta = \theta_P$, all of the reflected light is linearly polarized with the electric field axis parallel to the surface.

$$\tan\theta_P = \frac{n_2}{n_1}$$



*Review the Powerpoint slides on "Polarization" located on the course page:

http://facstaff.cbu.edu/~jvarrian/252/252PolWeb/252PolAbs.ppt