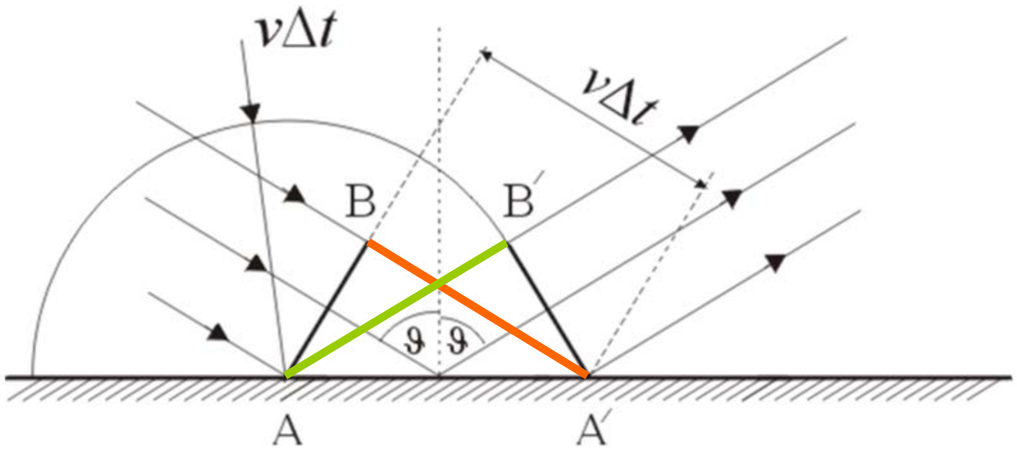
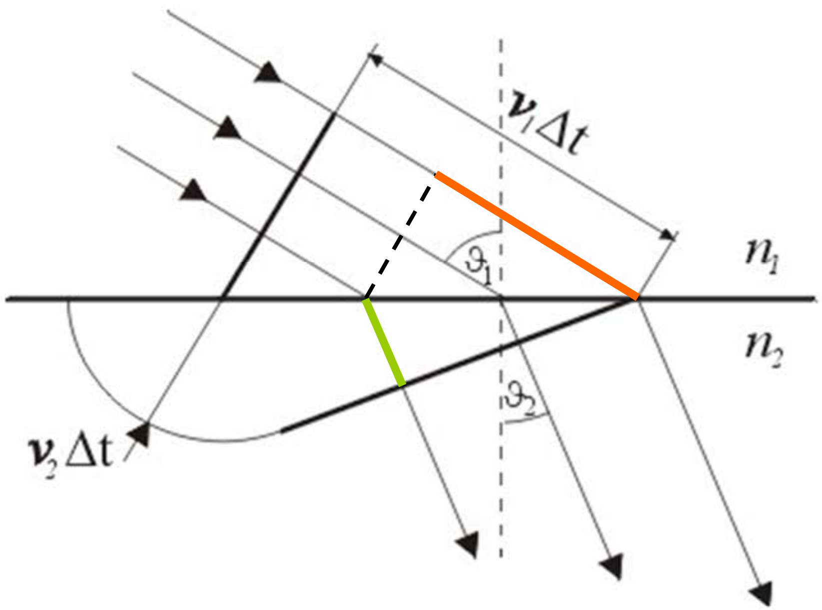
Physical (Wave) Optics

monochromatic harmonic wave $E(x,t) = E_0 \sin(kx - \omega t)$



Snell's law of reflection



Snell's law of refraction

Fresnel Equations of reflection and refraction

– **Refraction** at an interface **never** causes a phase change

– If the incident wave is traveling in the medium of **greater index** of refraction – **no phase change** after reflection.

– If the incident wave is traveling in the medium of **lower index** of refraction – **change of phase by π** after reflection.

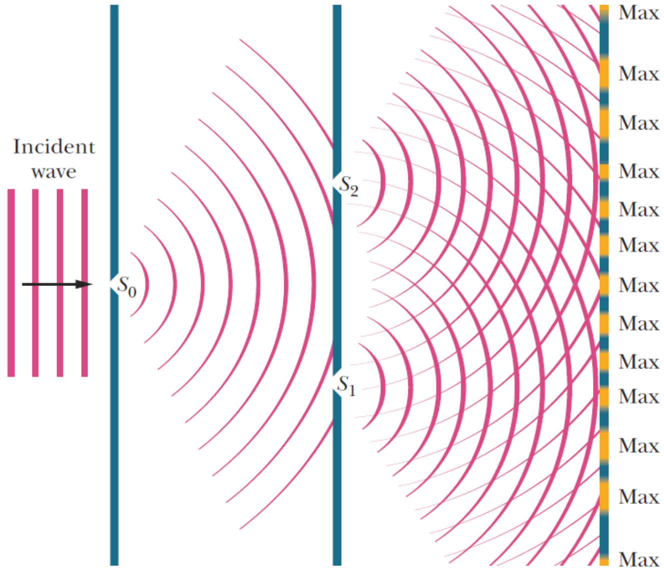
Interference of light

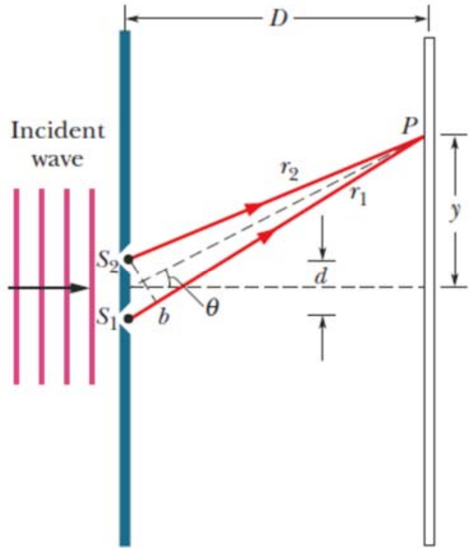
The waves should be **monochromatic** or quasimonochromatic.

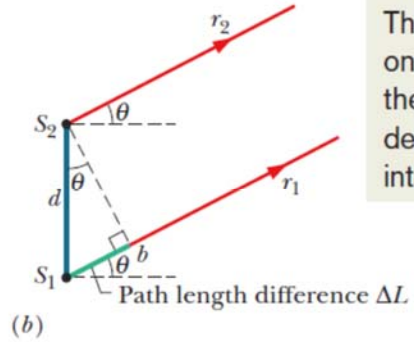
The sources of the waves must be **coherent**, which means they emit identical waves with a constant phase difference.

The amplitudes or intensities of the interfering waves need to be equal or similar.

Young's interference experiment







The ΔL shifts one wave from the other, which determines the interference.

$$E_{12} = E_1 + E_2$$
$$= E_0 \sin(kx_1 - \omega t) + E_0 \sin(kx_2 - \omega t)$$

$$\Delta L = d \sin\theta \approx \frac{yd}{D}$$

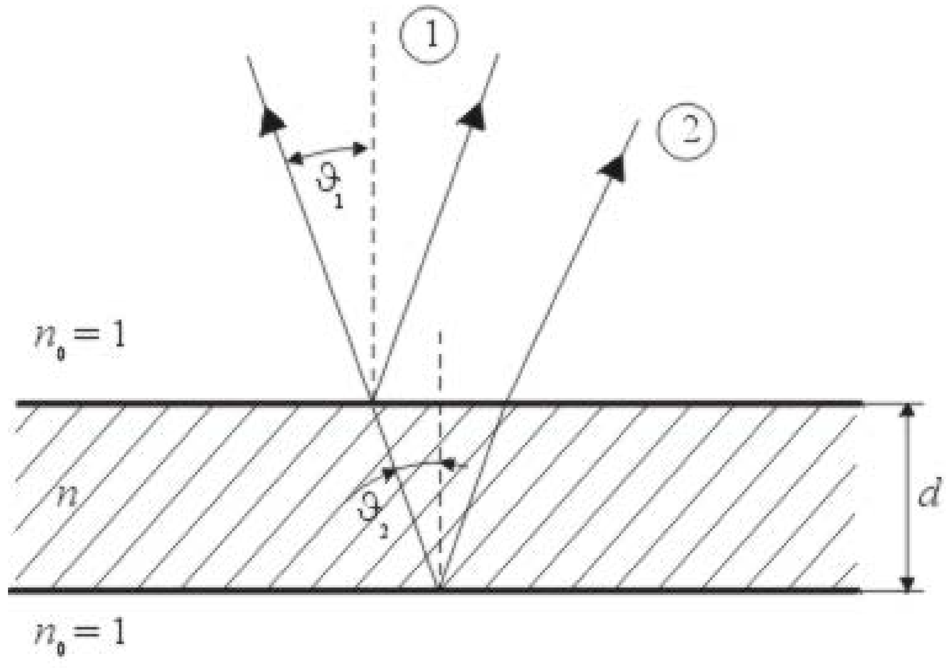
$$I \approx \left|\vec{E}_{10}\right|^2 + \left|\vec{E}_{20}\right|^2 + 2\vec{E}_{10} \cdot \vec{E}_{20} \cos\delta$$

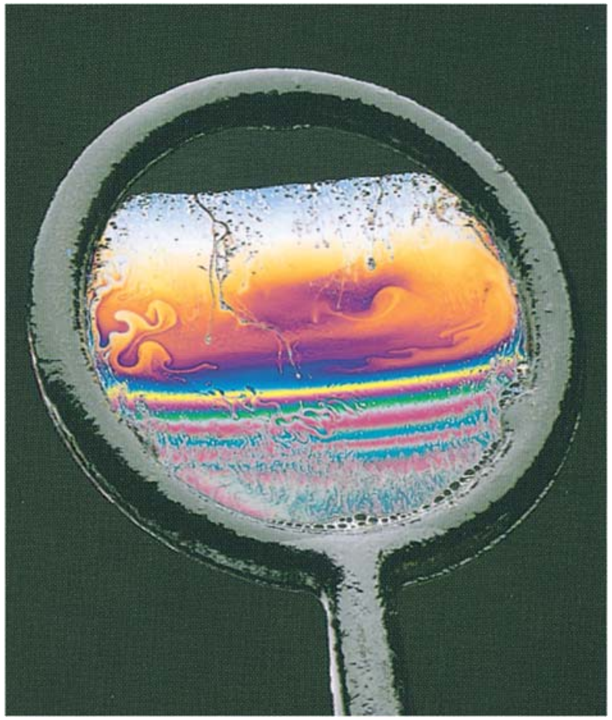
$$I_{12} = 4I_0 \cos^2\left[\left(\frac{\pi d}{\lambda D}\right) y\right]$$

$$I \approx 4E_{10}^2 \cos^2\frac{\delta}{2}$$

$$y_{max} = m\frac{yD}{d}$$

Interference from thin films





maxima

$$x_2 - x_1 = \Delta x = 2nd - \frac{\lambda}{2} = m\lambda$$

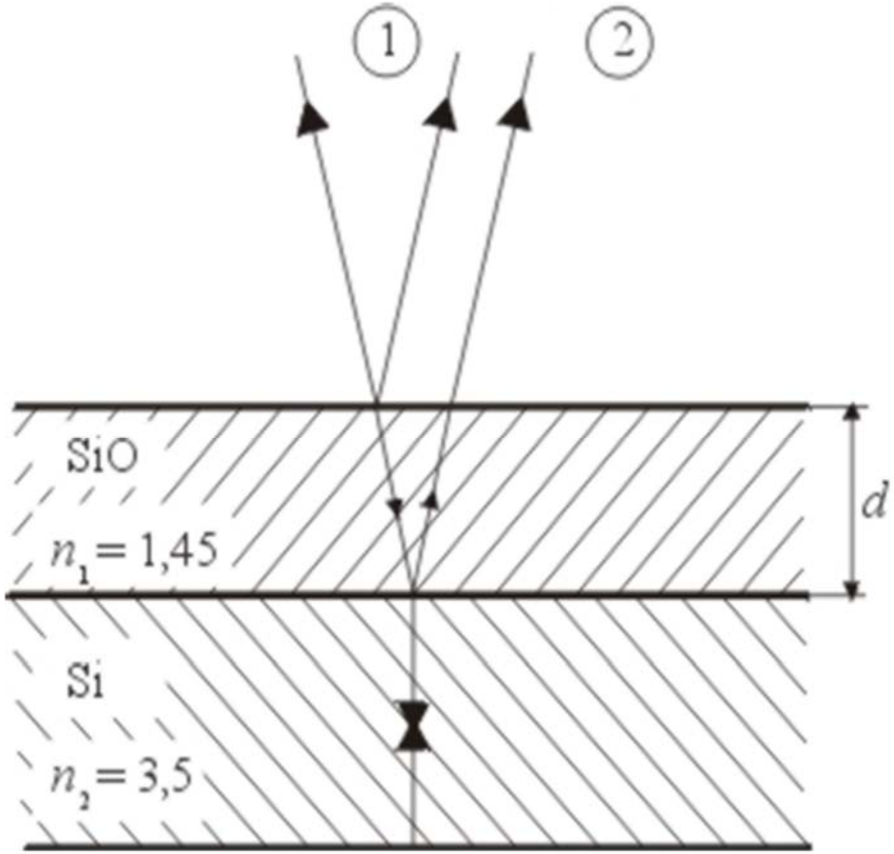
$$d = \frac{\lambda}{2n}\left(m + \frac{1}{2}\right)$$

minima

$$x_2 - x_1 = \Delta x = 2nd - \frac{\lambda}{2} = (2m-1)\frac{\lambda}{2}$$

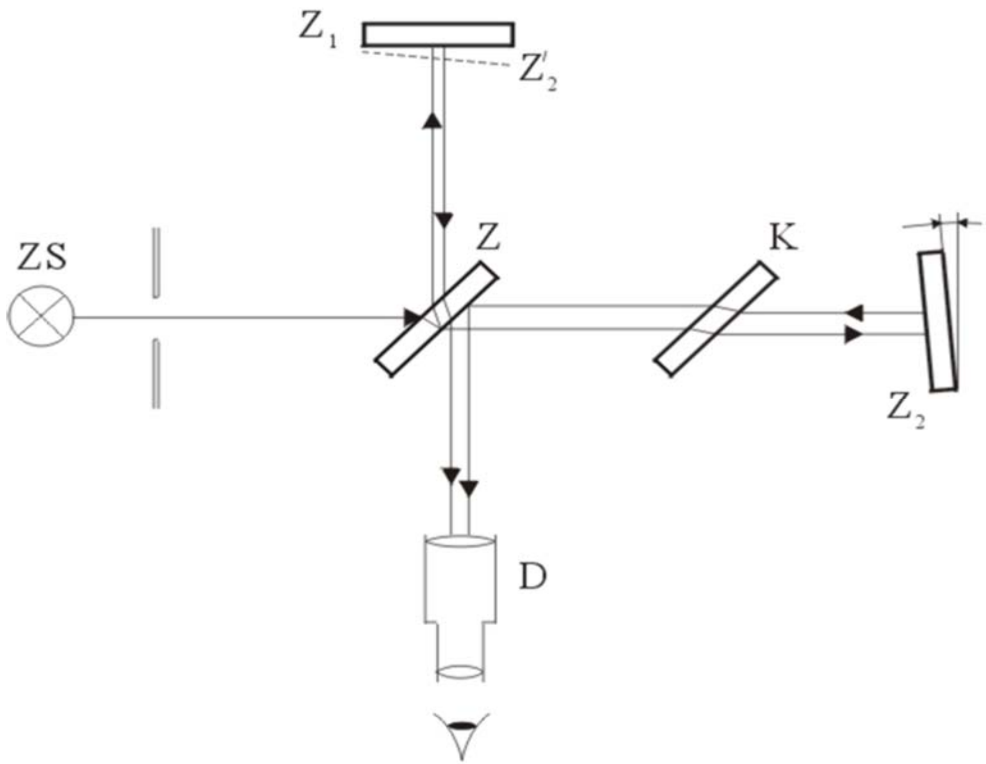
$$d = \frac{m\lambda}{2n}$$

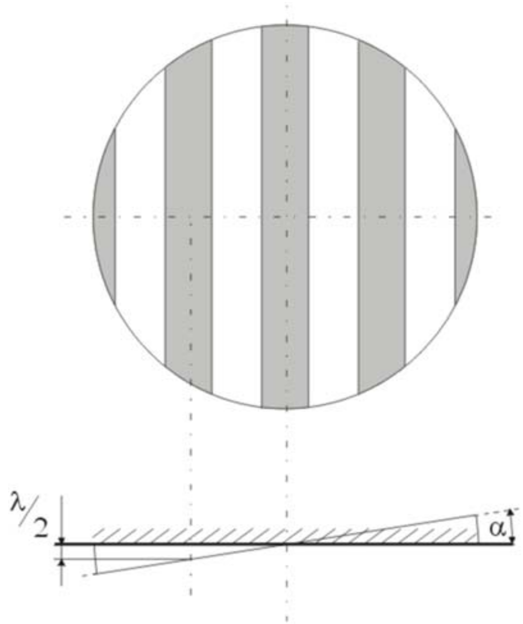
Anti-reflection coatings



$$x_2 - x_1 = \Delta x = 2nd = (2m-1)\frac{\lambda}{2}$$

Michelson’s Interferometer





$$\Delta x_{\max} = m\lambda,\ \ \Delta x_{\min} = (2m+1)\frac{\lambda}{2},\ \ m = 0, \pm 1, \pm 2, \ldots$$

Diffraction of light

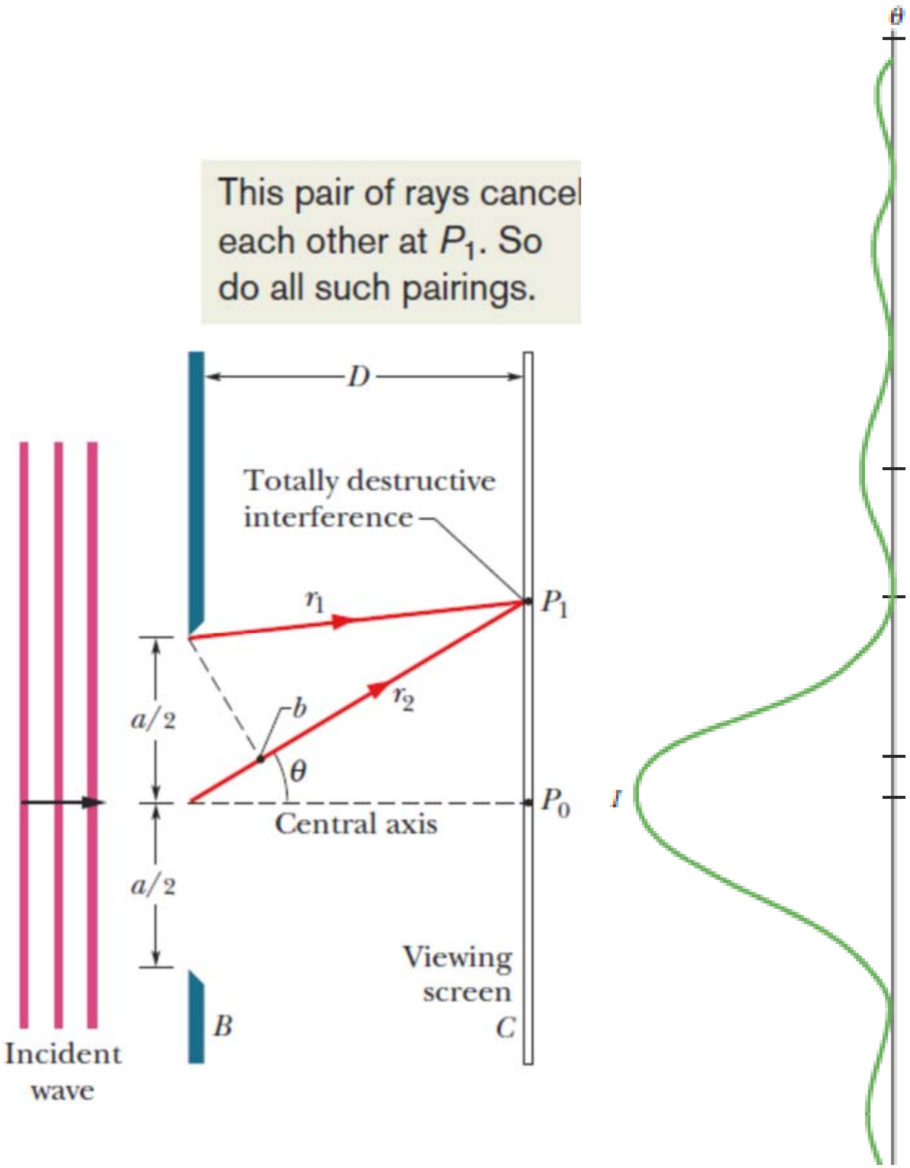
Single-slit diffraction

location of minima

$$a \sin \vartheta_m = \pm m\lambda \, , \qquad m = 1, 2, 3, \ldots$$

$$I = I_0 \left(\frac{\sin \alpha}{\alpha} \right)^2$$

$$\alpha = \frac{\pi a}{\lambda} \sin \vartheta$$

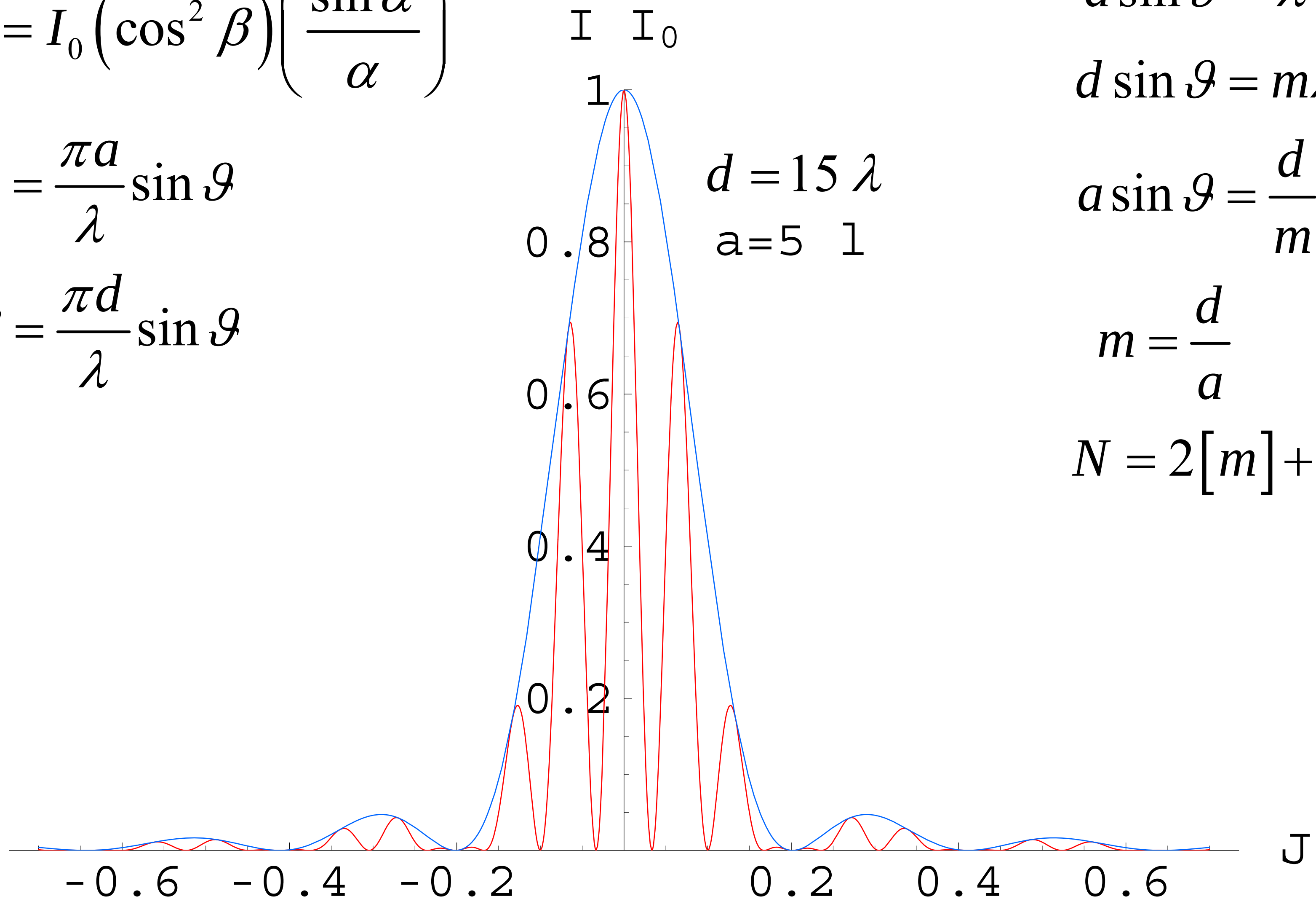


Double-slit diffraction

$$I = I_0 \left(\cos^2 \beta\right)\left(\frac{\sin\alpha}{\alpha}\right)^2$$

$$\alpha = \frac{\pi a}{\lambda}\sin\vartheta$$

$$\beta = \frac{\pi d}{\lambda}\sin\vartheta$$



1st minimum

$$a\sin\vartheta = \lambda$$

$$d\sin\vartheta = m\lambda$$

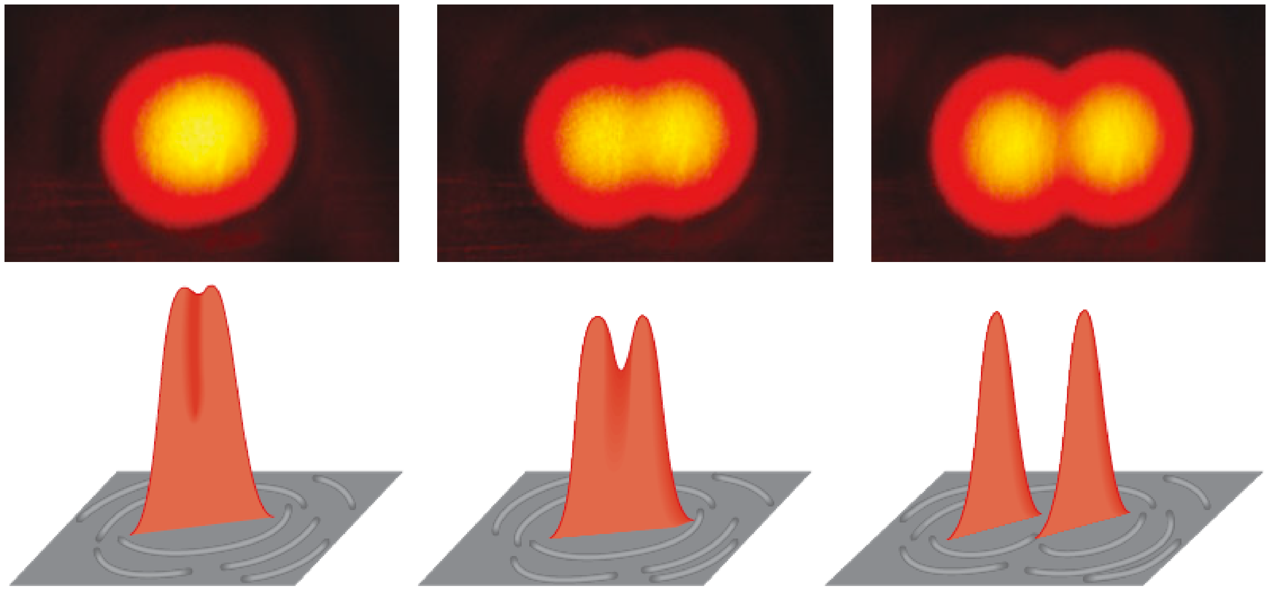
$$a\sin\vartheta = \frac{d}{m}\sin\vartheta$$

$$m = \frac{d}{a}$$

$$N = 2[m]+1$$

Circular aperture diffraction – optical resolvability

A visual resolvability for two distant point objects (stars, etc.) with small angular separation.

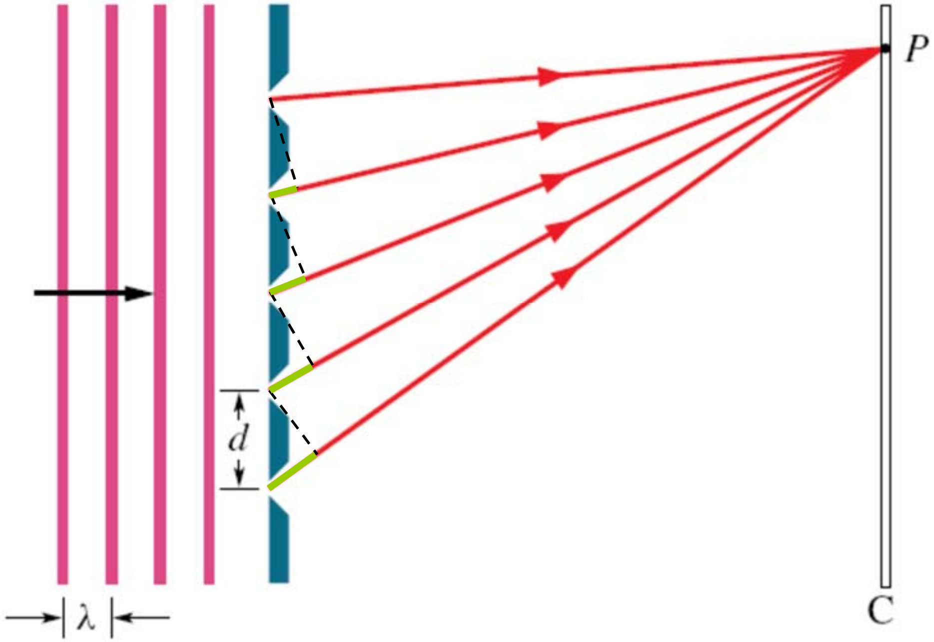


Rayleigh criteria

$$\theta_R = 1.22\frac{\lambda}{d}$$

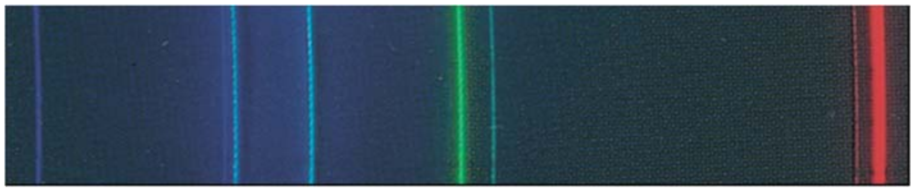
Pointillism

Diffraction gratings



positions of maxima

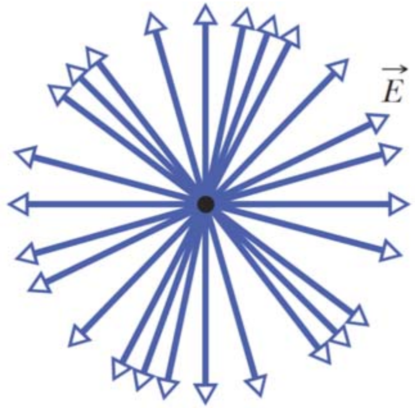
$$d \sin \alpha = k\lambda$$



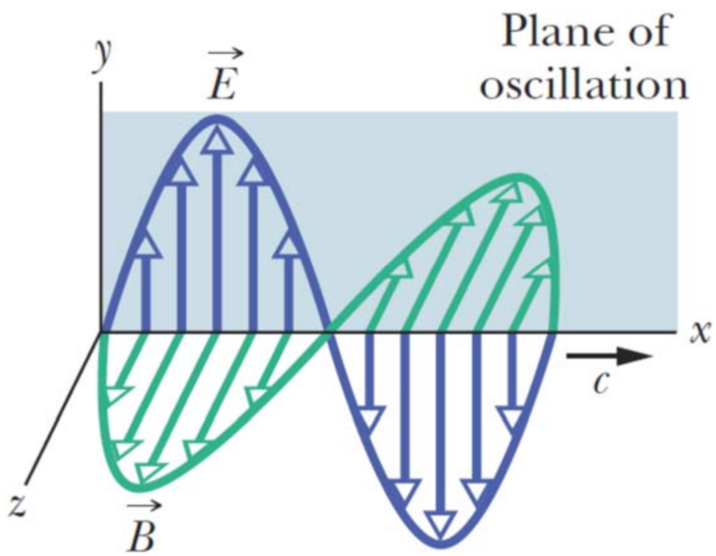
Polarization of light

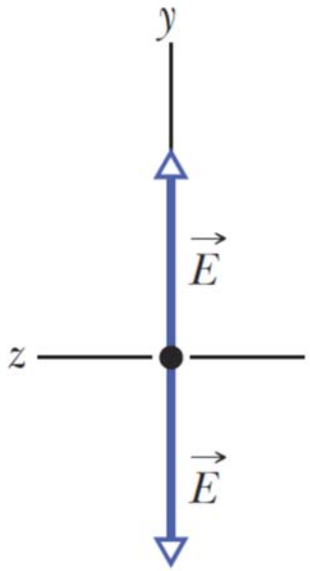
transversal plane: direction of $\vec{E}$ oscillations

random oscillations = randomly polarized

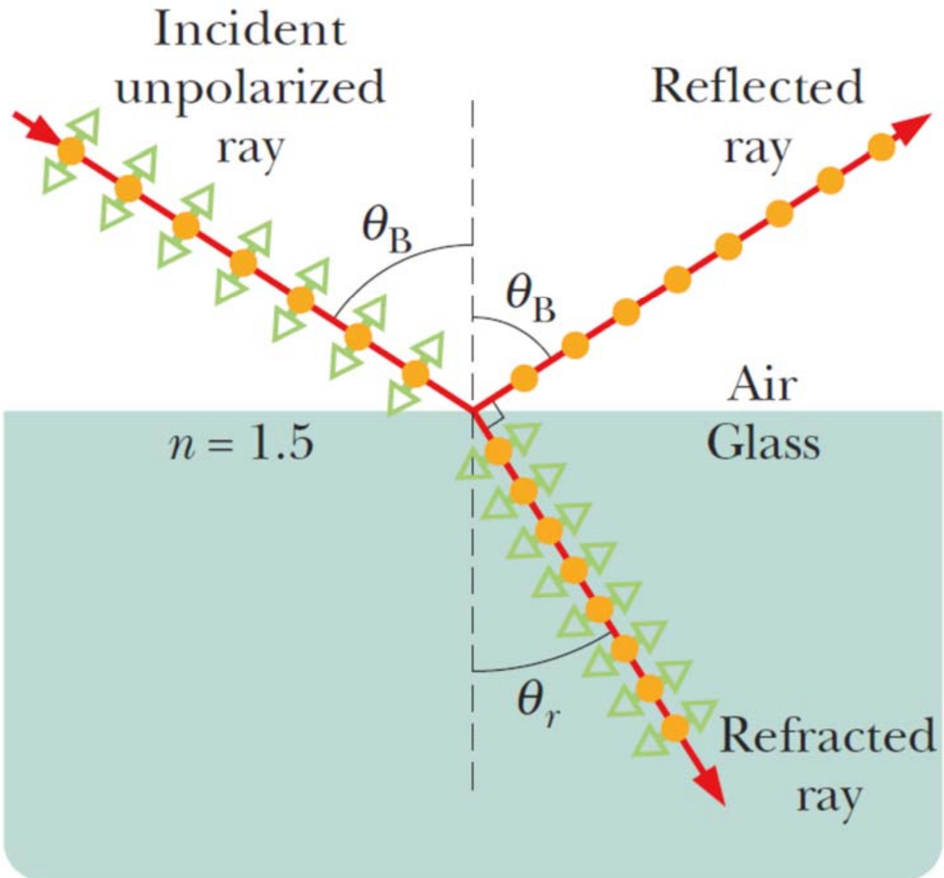


linearly polarized - $\vec{E}$ oscillates in-line



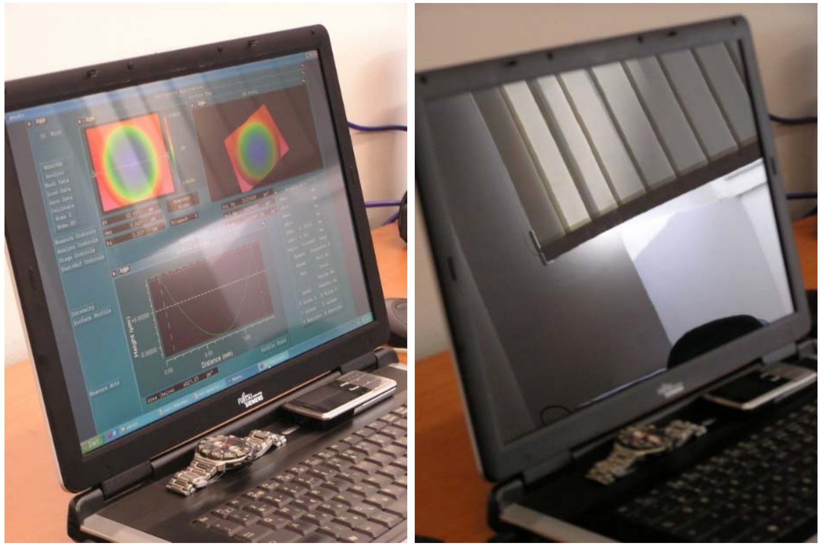


Polarization by reflection

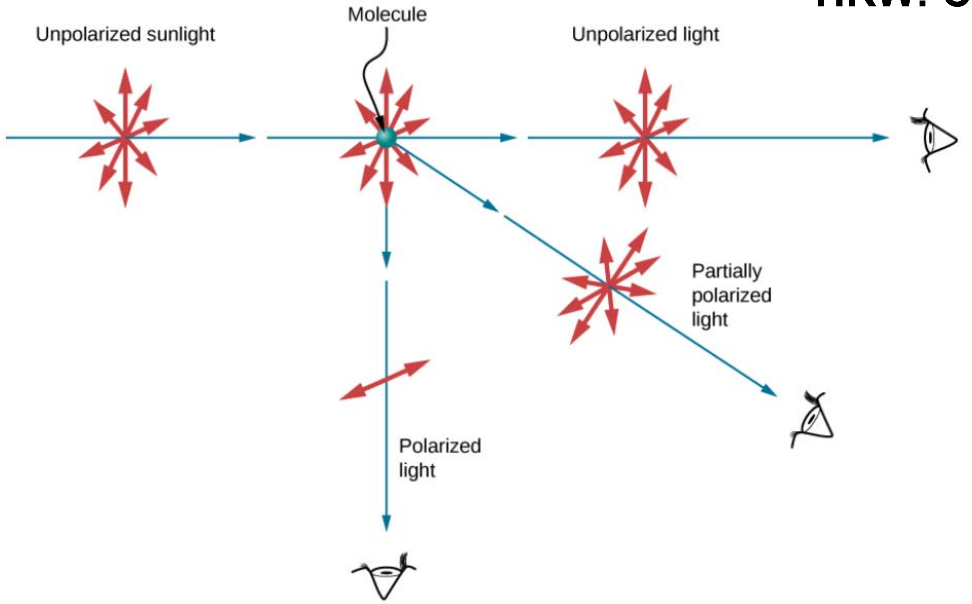


$$\tan \theta_B = n$$ Brewster angle

Polarization by reflection



Polarization by scattering



Polarization in anisotropic crystals

birefringence – calcite, quartz, ice
two beams: ordinary and extraordinary