Chapter 3

Optical components of spectrometers

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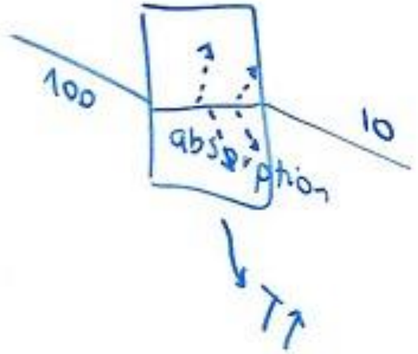
Chapter 3:

Optical components of spectrometers:

Conservation law



η: refractive index $= \frac{c}{V}$

$\eta = f(\lambda)$

V : velocity

ν : frequency

air glass

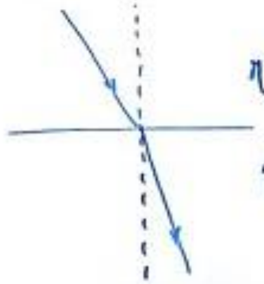
$E_1 = E_2$ if no absorption

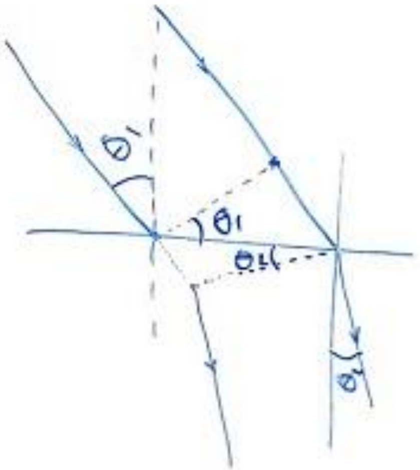
$h\nu_1 = h\nu_2$ No change in freq.

$\uparrow c = \lambda \nu$

$\downarrow V = \lambda_1 \nu_1$ $\rightarrow \lambda > \lambda_1$

refraction: شکست

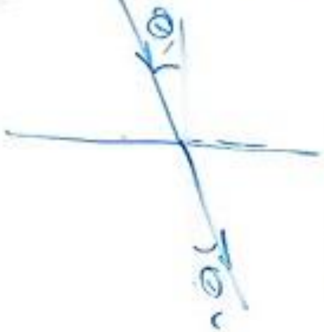




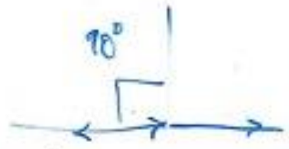
$\sin\theta_1 \, \eta_1 = \sin\theta_2 \, \eta_2$

Snell's law

$\eta_1 \simeq \eta_2 \rightarrow \sin\theta_1 = \sin\theta_2$



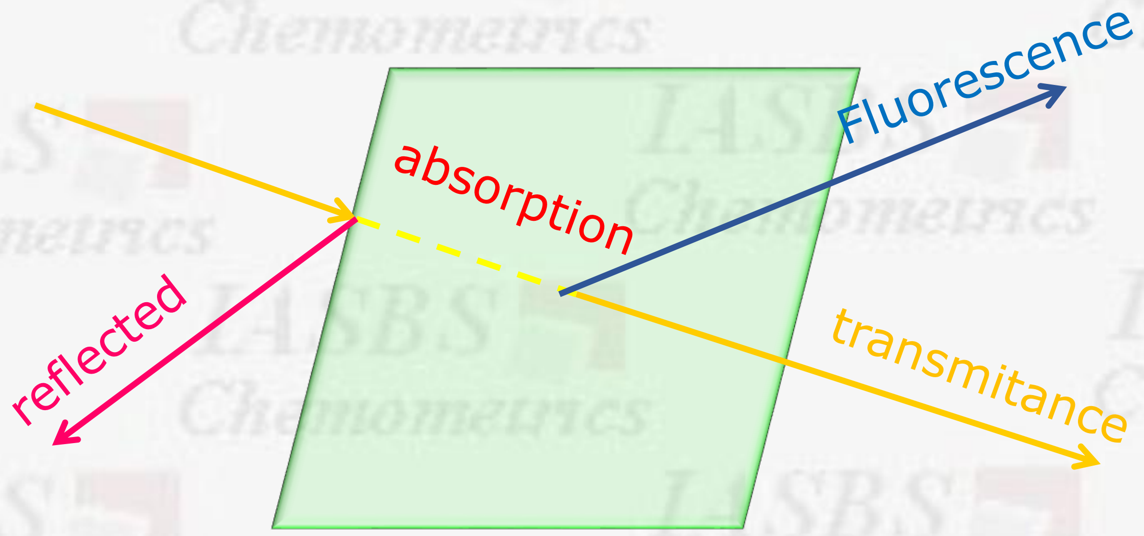
Fresnel law



min reflection

Conservation law

A basic principle of wave motion states that when a wave strikes a boundary between two media, a portion of the wave is reflected, a portion is absorbed, and a portion is transmitted into the new medium. This is often known as the conservation law.



Reflected fraction+ Absorbed fr.+ transmited fr.+Fluoresc Fr.=1

Reflection and refraction

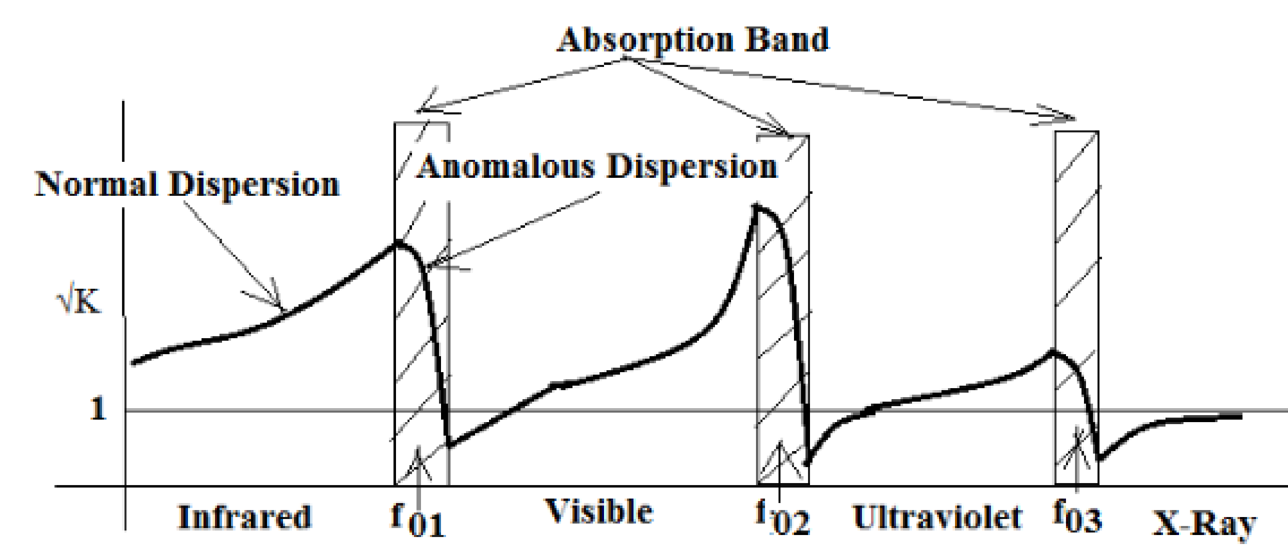
Maxwell Law:

$$\eta = \frac{c}{v} = \sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}}$$

$\varepsilon/\varepsilon_o$: Dielectric constants ratio >1,
$\varepsilon_o\,\mu_o$: Permeability (1/3e8)

Dispersion

$\eta = f(\lambda)$



$d\eta/d\lambda$ >>0 or <<0 : Anomalous Dispersion

$\eta = c/v$

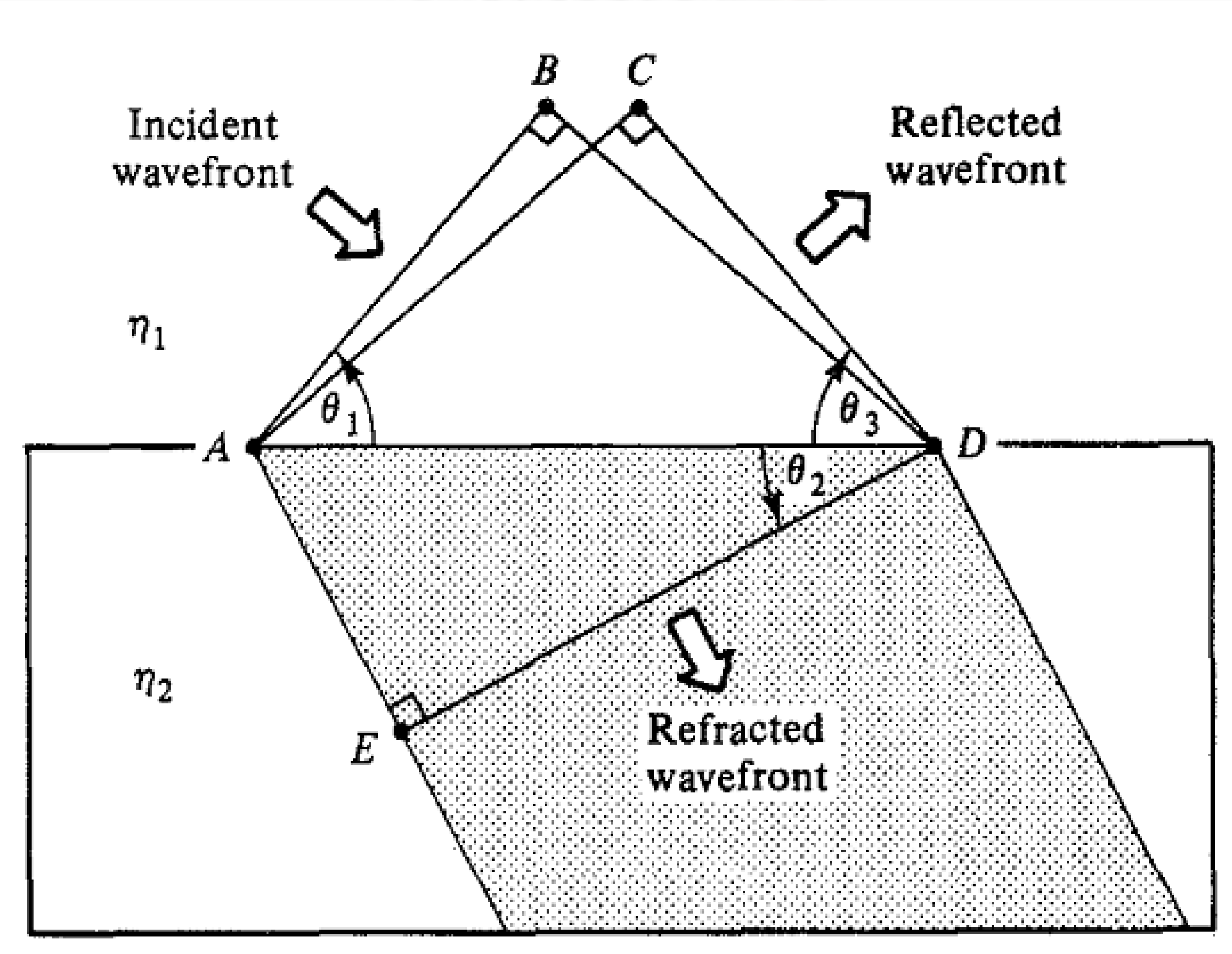
λ Change → η change → v change

$c = \lambda\nu$ in vacuum

$v = \lambda_1 \nu_1$ in new medium

$\nu_1 = \nu$ (no energy change)

& $c > v$ ➔ $\lambda > \lambda_1$



$\eta 1 = c/v1 = c/(BD/t)$
$\eta 2 = c/v2 = c/(AE/t)$

➔ $c\,t = \eta 1\, BD = \eta 2\, AE$

➔ $\sin\theta 1\, \eta 1 = \sin\theta 2\, \eta 2$

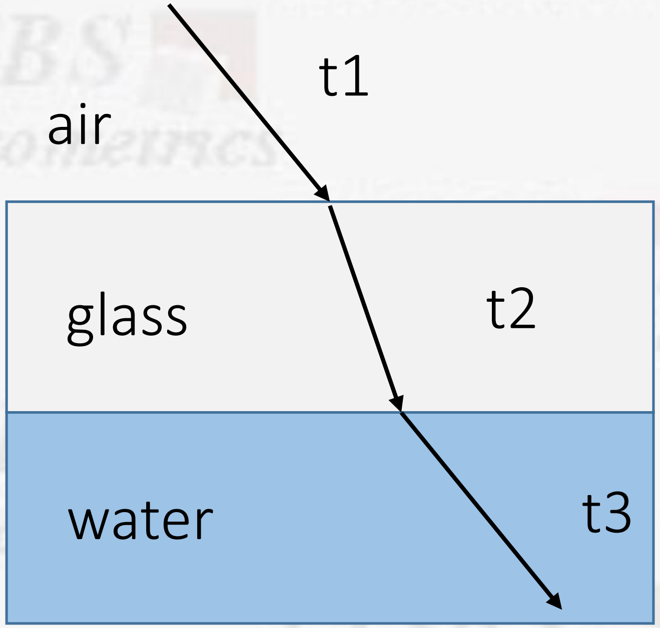
Snell's Law

$\theta 1 = \theta 3$ reflection

$\sin\theta 1 = BD/AD$, $\sin\theta 2 = AE/AD$

Using common AD:

$\sin \theta 1 / BD = \sin \theta 2 / AE$



$t = t1 + t2 + t3 \qquad v = x/t$

$= x1/v1 + x2/v2 + x3/v3 = \Sigma\, xi/vi$

$, \eta = c/v$

➔ $t = \Sigma\,(xi\ \eta i)/c$ Optical pathlength, OPL

The distance light passes in vacuum in time t.

Fresnel Law:

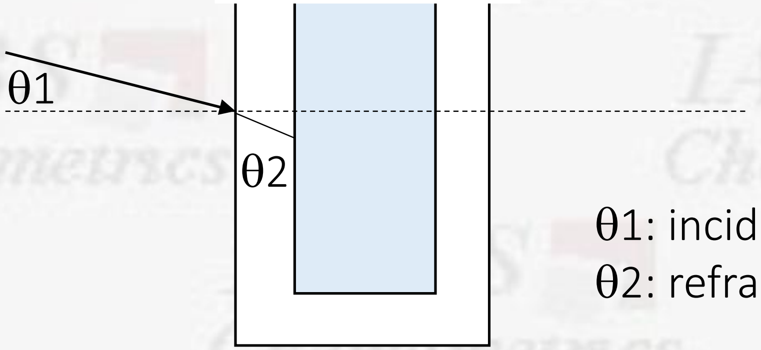
Reflection fraction

Normal, 90^o:

$\rho(\lambda) = [(\eta 2 - \eta 1)/(\eta 1 + \eta 2)]^2$

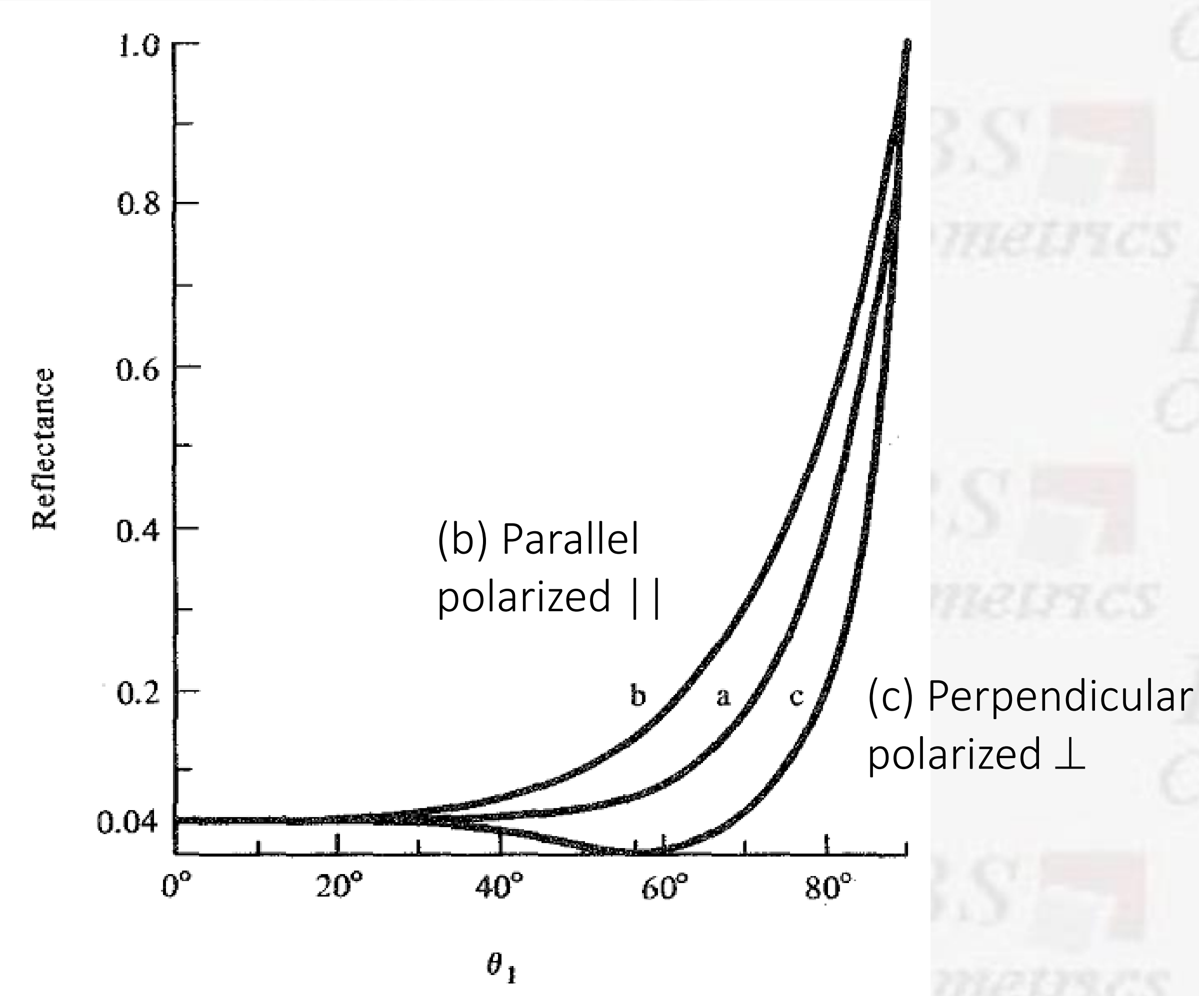
Other than 90^o (General form):

$$\rho(\lambda) = \frac{1}{2}\left[\frac{\sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)} + \frac{\tan^2(\theta_1 - \theta_2)}{\tan^2(\theta_1 + \theta_2)}\right]$$



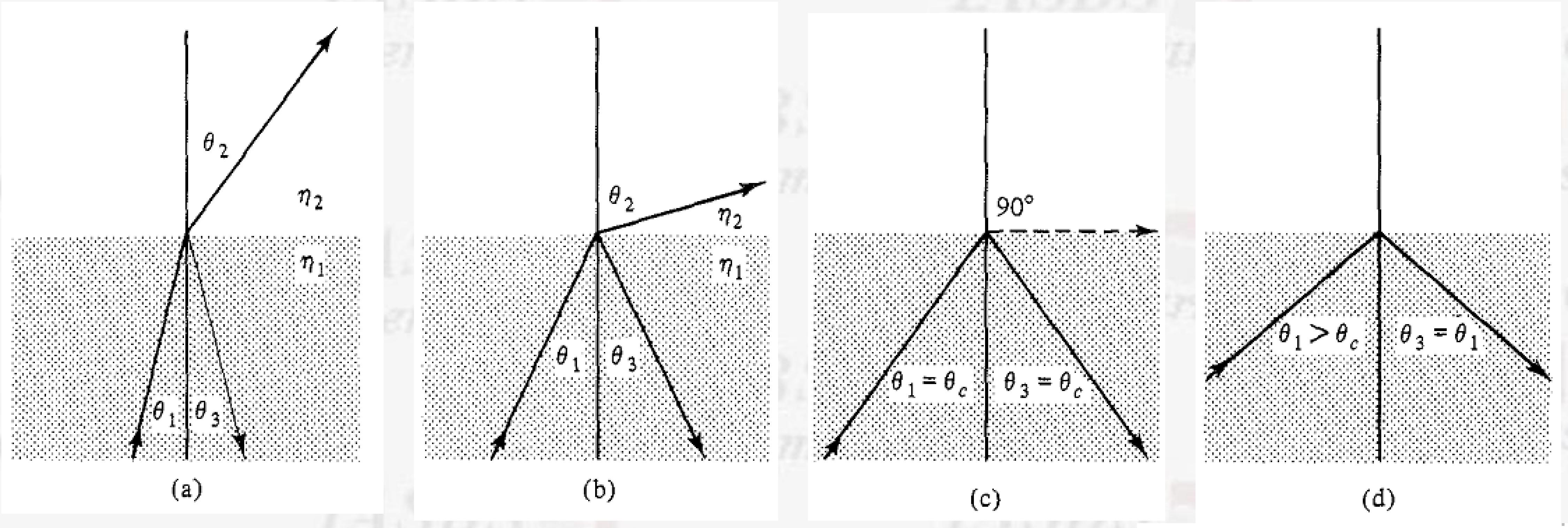
θ1: incident
θ2: refracted

Fresnel Law: $$\rho(\lambda) = \frac{1}{2}\left[\frac{\sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)} + \frac{\tan^2(\theta_1 - \theta_2)}{\tan^2(\theta_1 + \theta_2)}\right]$$



56° : Brewster Angle

Total internal reflection



$$\sin \theta_1 = (\eta_2/\eta_1) \sin \theta_2,$$

at $\theta_2 = 90°$, $\theta_c = \sin^{-1}(\eta_2/\eta_1)$.

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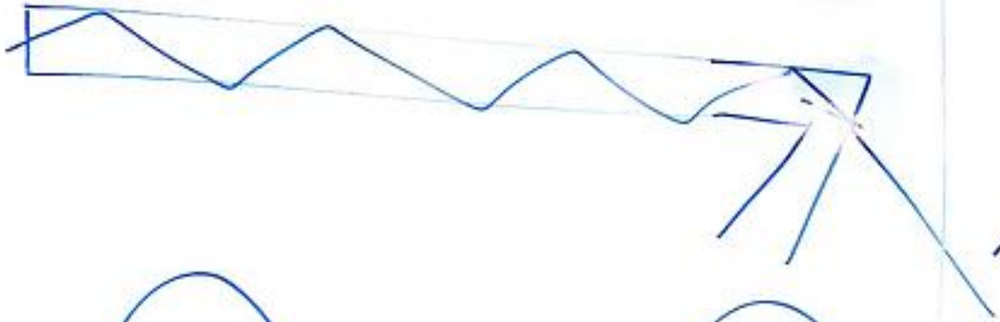
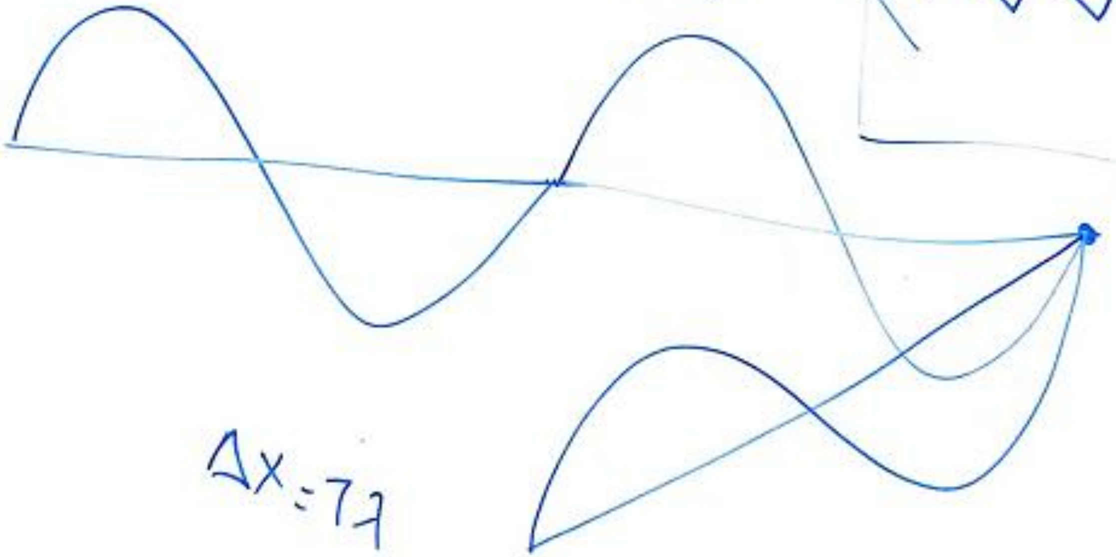
Total Internal reflection

→ optical fibers





$\Delta x = 7\lambda$

a Large number slits

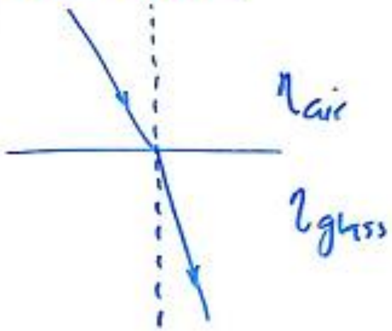
↓

grating

DVD drive

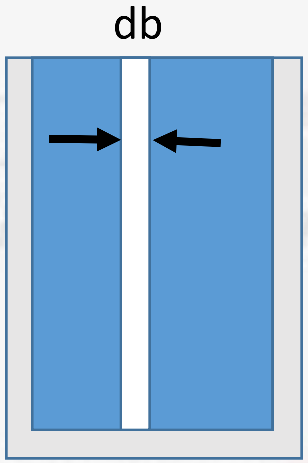
CD dri…

refraction: شکست



$\eta_1 \approx \eta_2 \rightarrow \sin\theta_1 = s$…

Absorption Law:



$$d\Phi = -k\Phi \, db$$

k: absorption coefficient

UV: Quartz
Visible: Glass

$\alpha = 1 - T$
Absorbance

$$\rightarrow \int_{\Phi_0}^{\Phi} \frac{d\Phi}{\Phi} = -k \int_0^b db \rightarrow \ln \frac{\Phi}{\Phi_0} = -kb = -A = \varepsilon b c$$

Absorption (A)

Absorptivity (ε)

Electromagnetic radiation:

is a **transverse wave**.

(Direction of oscillation is perpendicular to direction of propagation).

$$E = E_m \sin[(\omega t) - (kx + \phi_0)]$$

ϕ = $(kx + \phi_0)$

θ = $[(\omega t) - (kx + \phi_0)]$

$$k = 2\pi/\lambda$$

$$\omega = 2\pi\nu$$

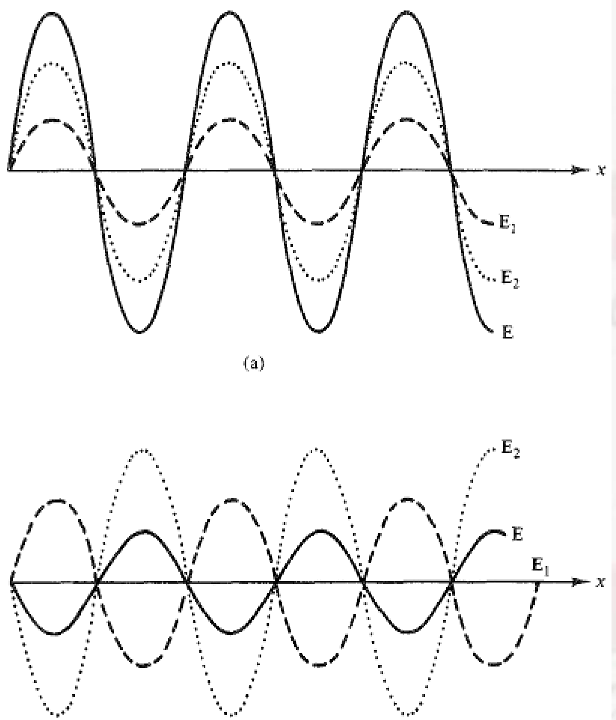
Longitudinal wave: Direction of oscillation is parallel to direction of propagation

principle of superposition

$$E = E_1 + E_2$$
$$= E_{m1}\sin(\omega t + \phi_1) + E_{m2}\sin(\omega t + \phi_2)$$

$$E = E_m \sin(\omega t + \phi)$$

$$E_m^2 = E_{m1}^2 + E_{m2}^2 + 2E_{m1}E_{m2}\cos(\phi_2 - \phi_1)$$



Electromagnetic radiation:

$$\mathbf{E} = \mathbf{E}_m \sin[(\omega t) - (kx + \phi_0)]$$

($\phi = kx + \phi_0$; $\theta = (\omega t) - (kx + \phi_0)$)

$$k = 2\pi/\lambda$$

$$\omega = 2\pi\nu$$

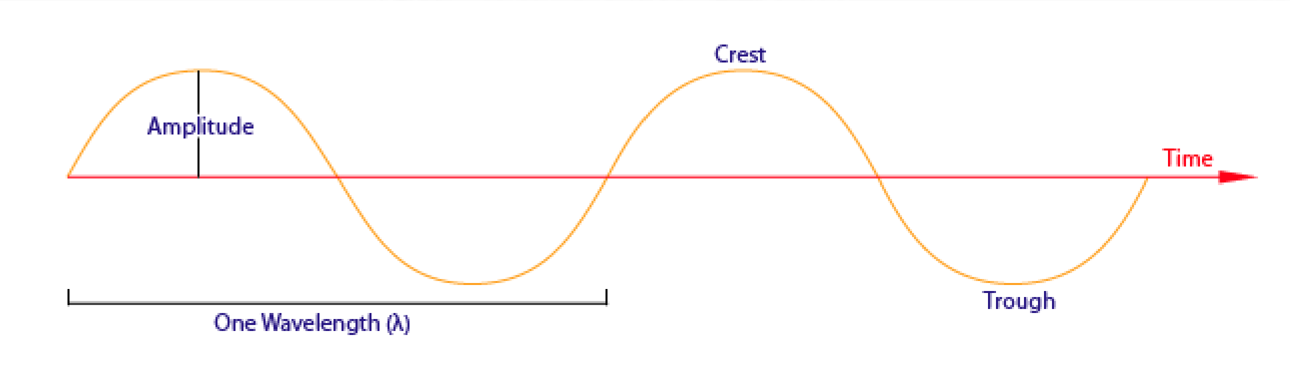
Example:

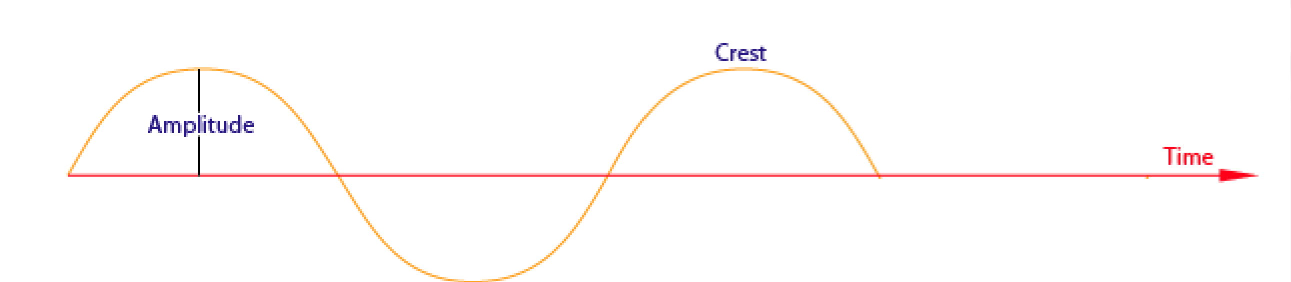
$\omega 1 = \omega 2$, $\lambda 1 = \lambda 2$, $\phi_0 1 = \phi_0 2$, $x1 \neq x2$

$\Delta\theta = \theta 2 - \theta 1 = 2\pi\, x2/\lambda - 2\pi\, x1/\lambda = 2\pi\, \Delta x/\lambda$

If $\Delta x = 1\lambda \rightarrow \Delta\theta = 2\pi$ (constructive interference)

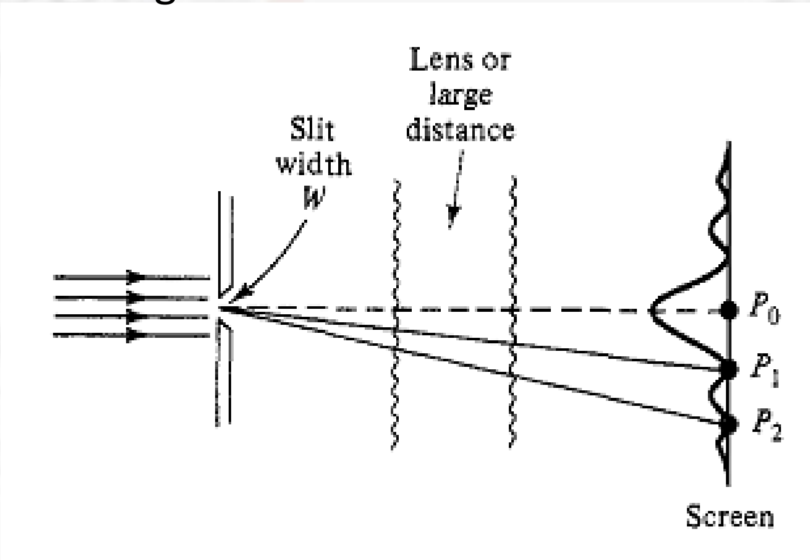
If $\Delta x = 0.5\lambda \rightarrow \Delta\theta = \pi$ (Destructive interference)



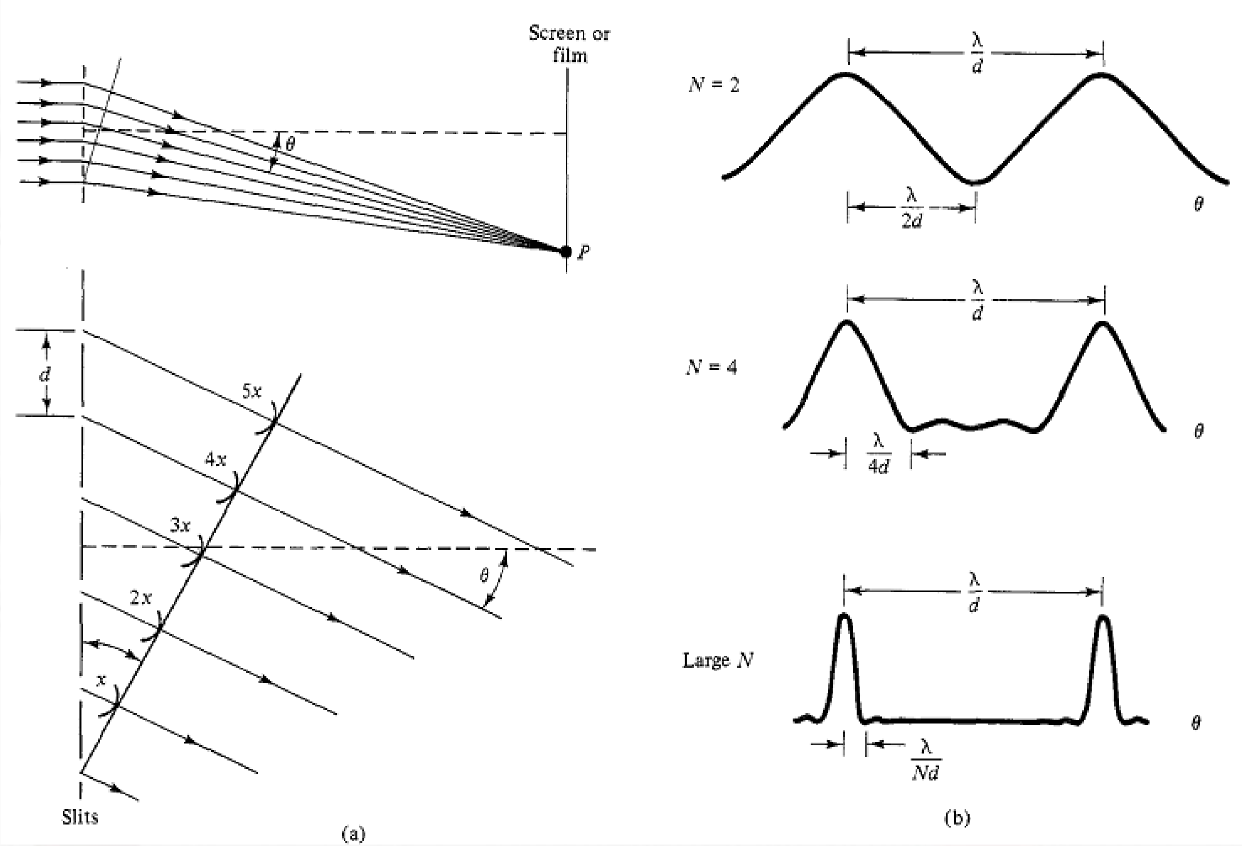


Fraunhofer diffraction:

At a single slit



At multiple slits



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