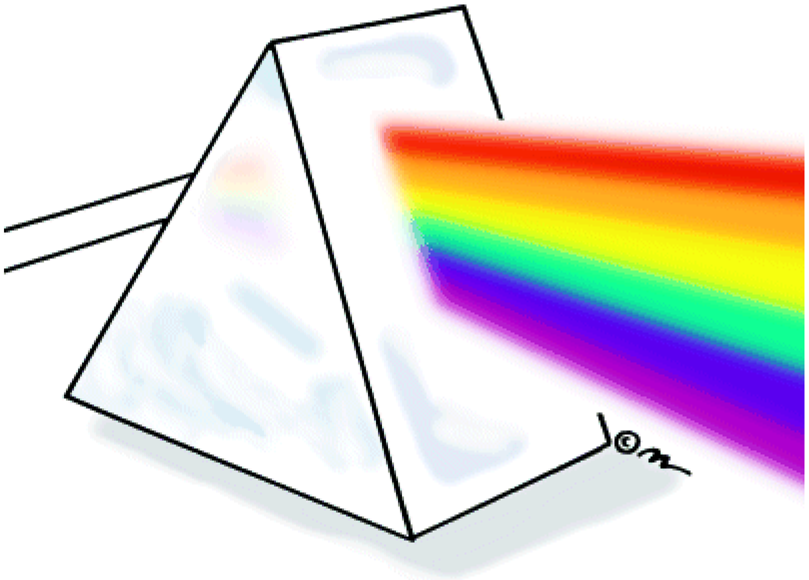
REVIEW OF OPTICS



Department of Engineering Physics

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Overview

- Light
- Reflection
- Refraction
- Lenses
- Mirrors

Light

- Light is the portion of electromagnetic radiation that is visible to the human eye. (400 nm - 700 nm)

- Optics is the branch of physics studying on
  - reflection
  - refraction
  - interference
  - diffraction
  - polarization
  - etc.

- Optics has many engineering applications based on the construction of instruments to use and detect the light.

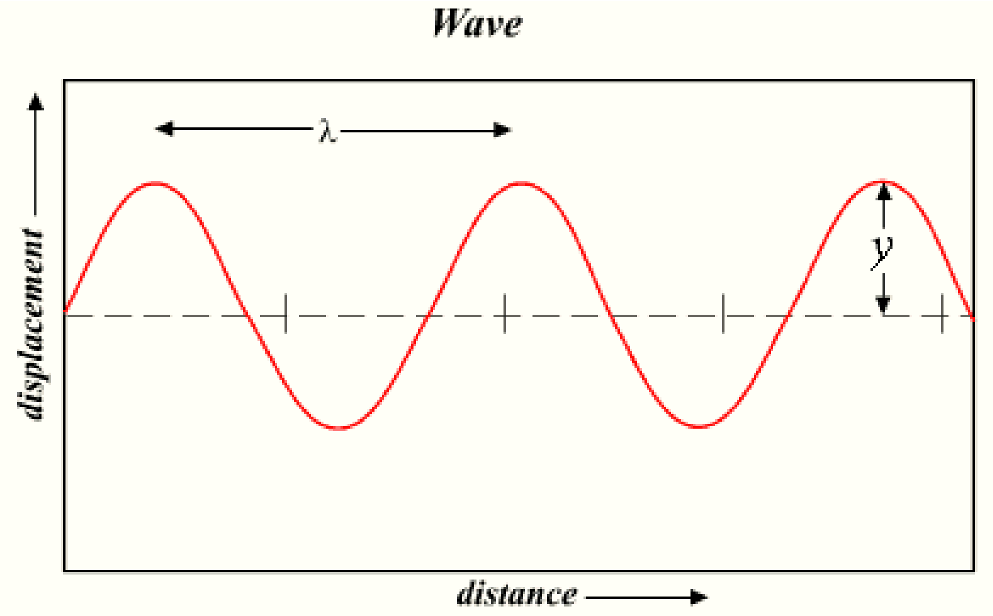
Geometric Optics

- GO is the study of light without diffraction and interference.

- First order optics is the study of perfect systems
(no aberration)

- Aberrations are the deviations from perfect systems.

Wave Nature of Light



λ : wavelength

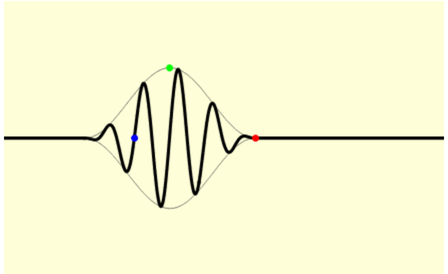
f : frequency (number of oscillations per second)

v : speed of the wave **--> v = *f* λ**

For a light in vacuum $v = c = 2.99792458 \times 10^8$ m/s

Quantum Theory of Light

Energy of photon is given by:



a wave packet

$$E = hf = \frac{hc}{\lambda}$$

h is the Planck's Constant (h = 6.6 x 10^{-34} J.s)
c is the speed of light (c = 3×10^{8} m/s)

Refraction Index

- The speed of light in any material is less than its speed in vacuum.

- The index of refraction, *n*, of a medium can be defined as

$$n \equiv \frac{\text{speed of light in a vacuum}}{\text{speed of light in a medium}} = \frac{c}{v}$$

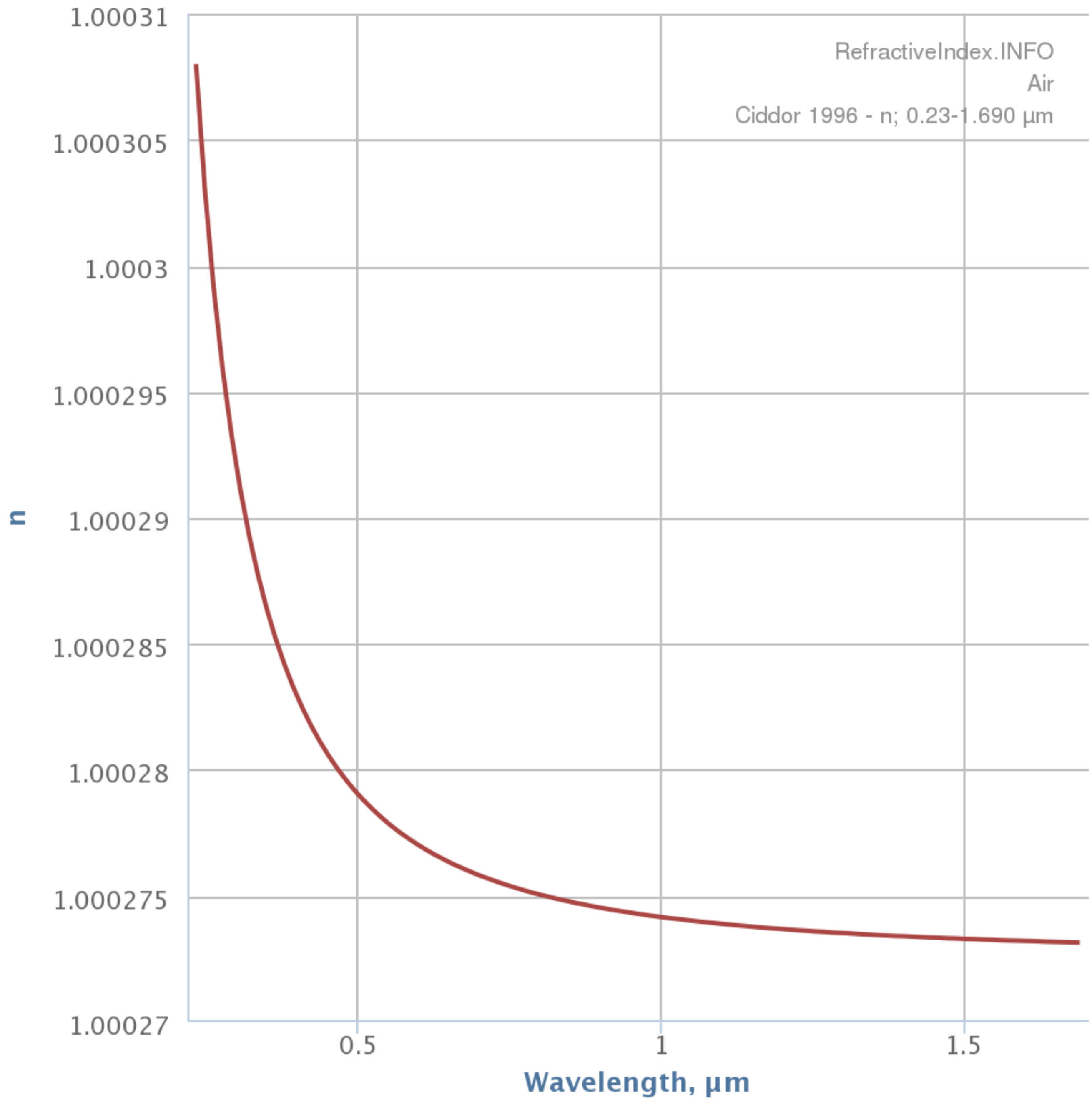
- For a vacuum: n = 1
  For air: n = 1.00029
  For water: n = 1.333

See also: http://refractiveindex.info

Dispersion:

n depends on wavelength.

n = f(λ)



http://refractiveindex.info

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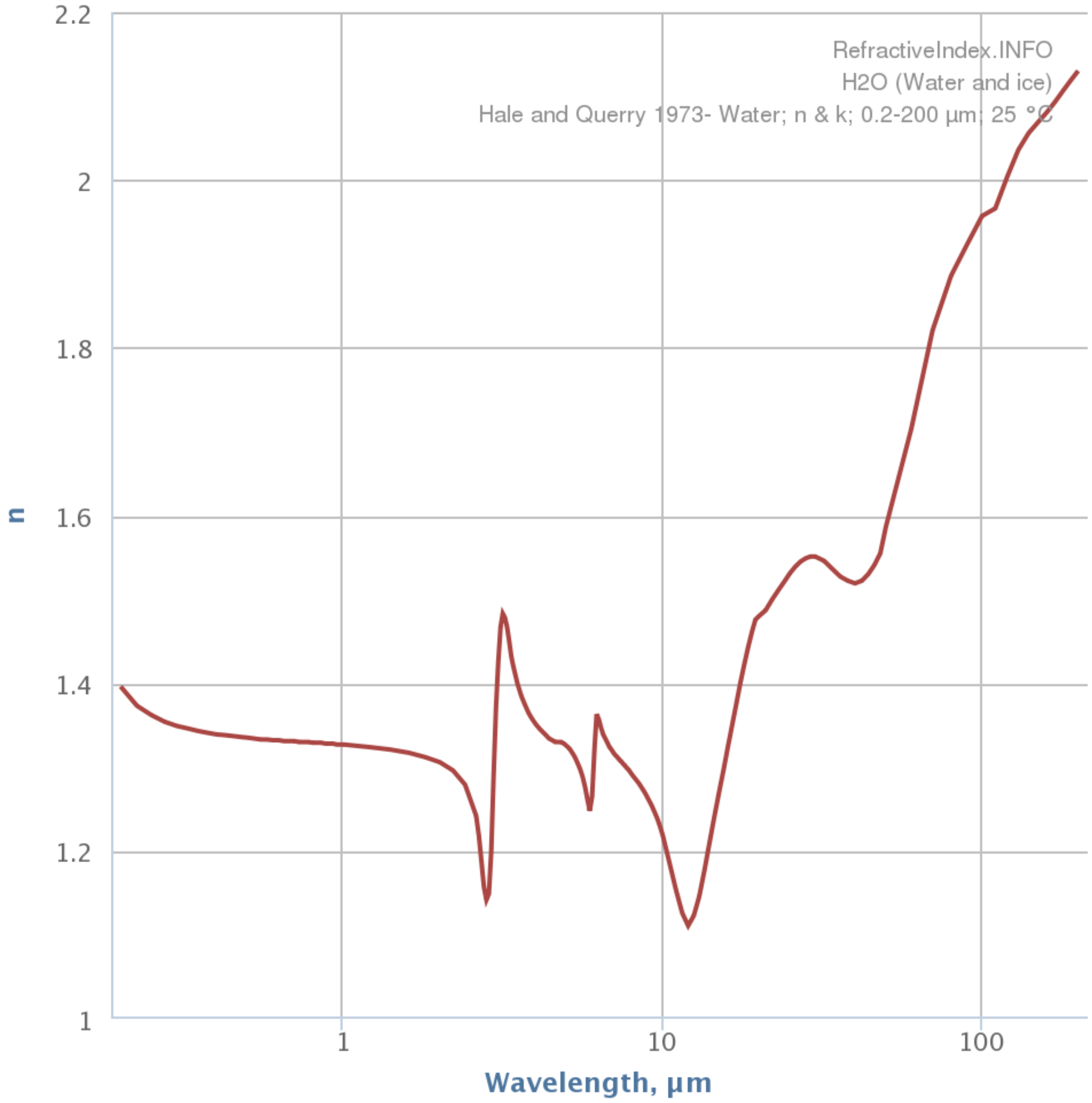

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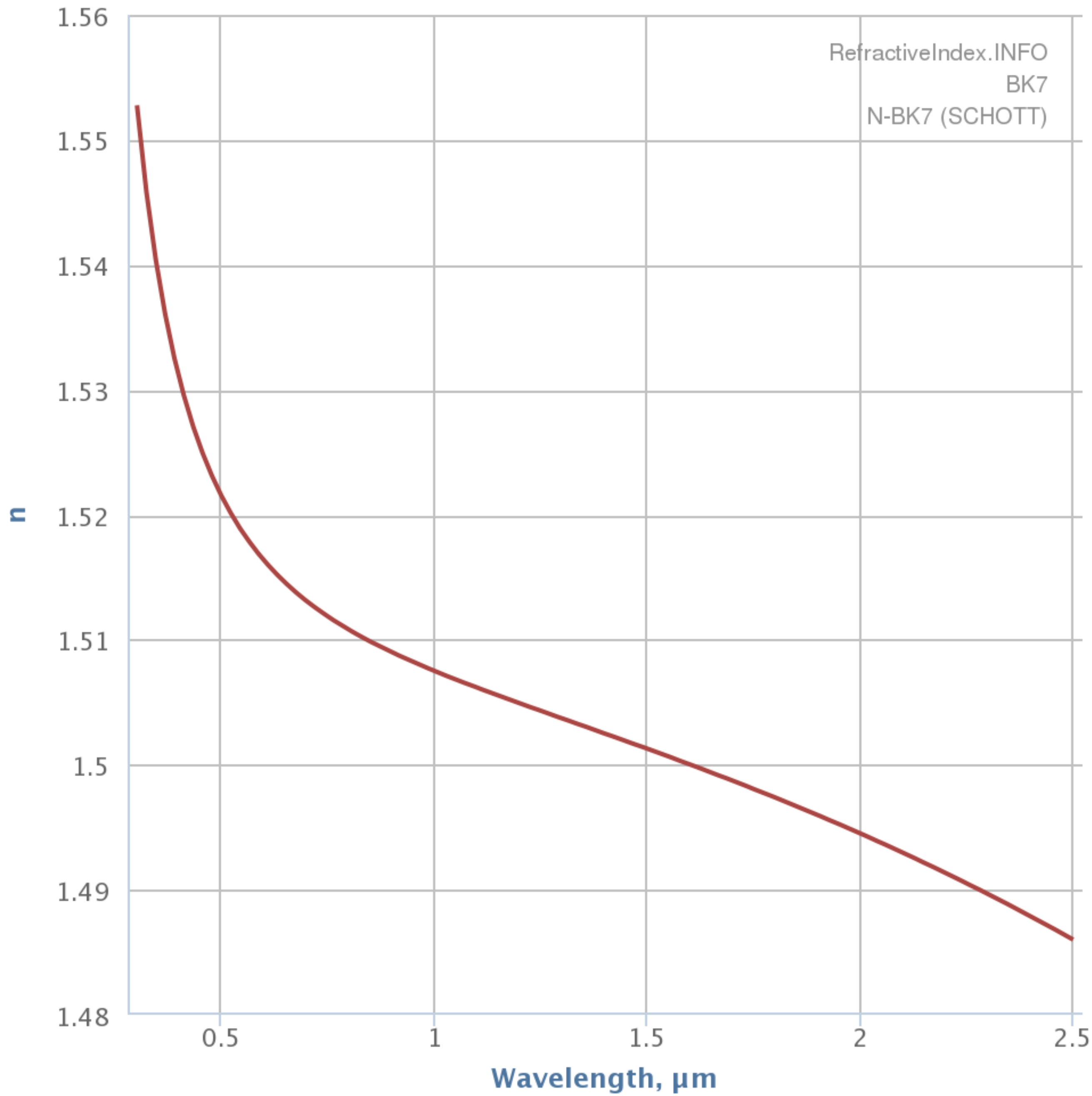


http://refractiveindex.info

Abbe Number

One way of characterizing dispersion is the Abbe number (V):

$$V = \frac{n_D - 1}{n_F - n_C}$$

where

nF = ref.index at 486.1 nm (blue)

nD = ref.index at 589.3 nm (green)

nC = ref index at 656.3 nm (red)

Typical values range from about 20 to 70.

Larger V indicates a smaller change in index.

Temperature Effect

Unfortunately, index of refraction is also function of temperature.

- *Glass expands/contracts*

- *Mecahnical holders expands/contracts*

- *It is important to account for the other effects is temperature change is more than 10 degrees.*

Example for BK7:

dn/dT = 2.2e-6 (at 546 nm)
Over 50 oC => n changes by 0.00011

Thermal Coefficient of Expansion (TCE)

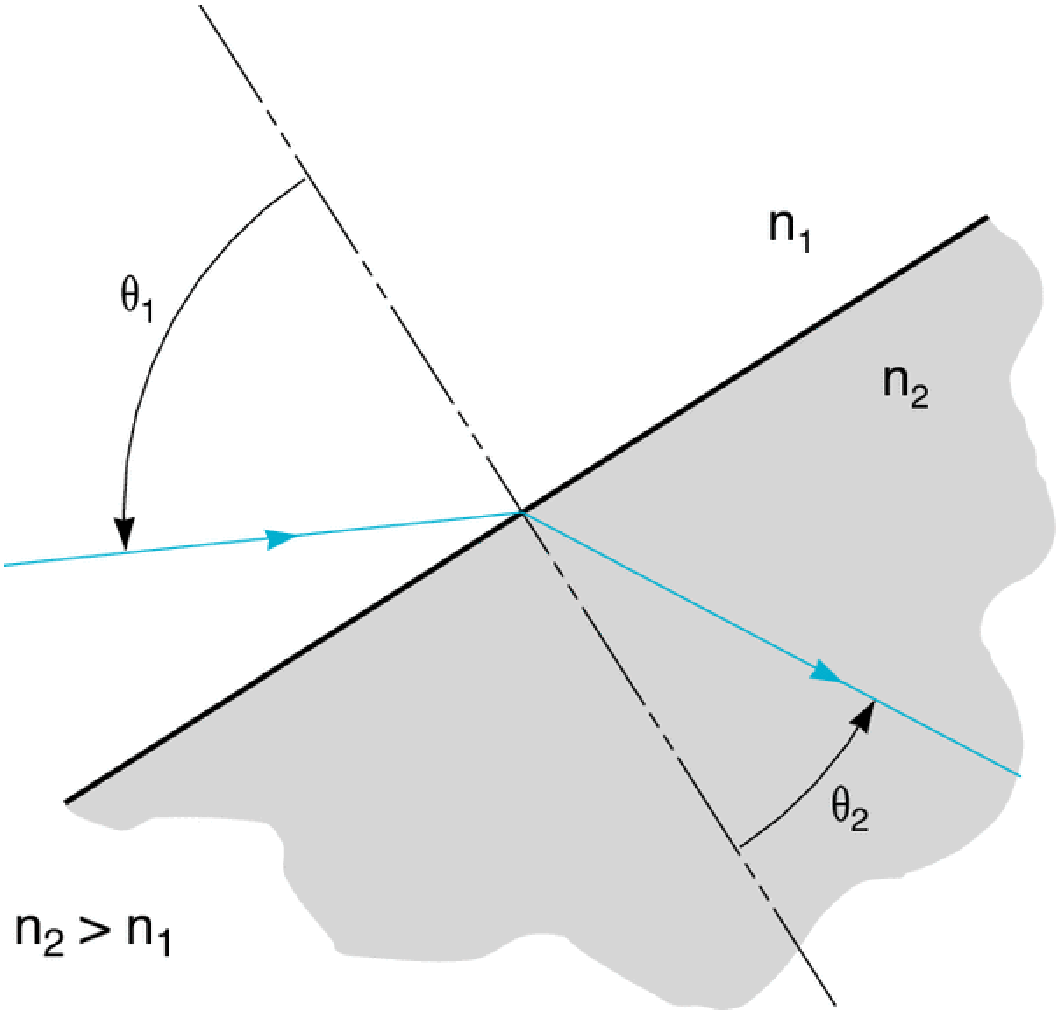
TCE for BK7 at T = 0 degrees is 7.1e-6.

After 50 degrees change, a glass with radius 100 mm becomes 100.0355.

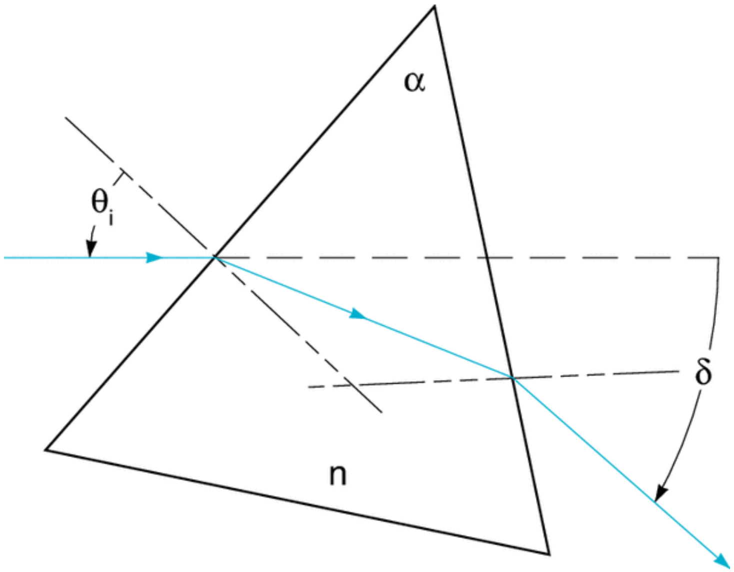
ZEMAX allows the user to input TCE data.

Snell's Law

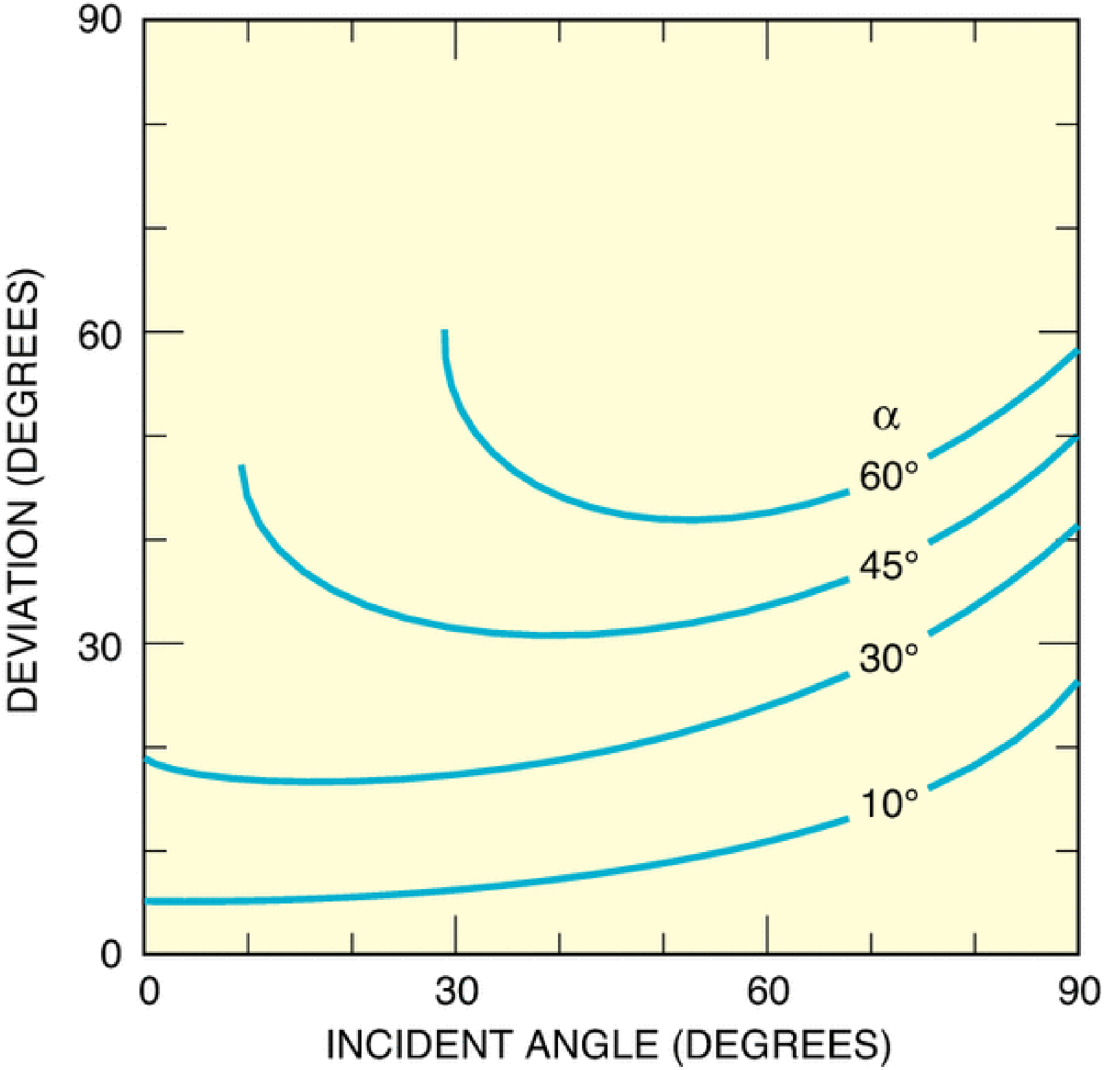
$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$



Prism



α
θ_i
δ
n

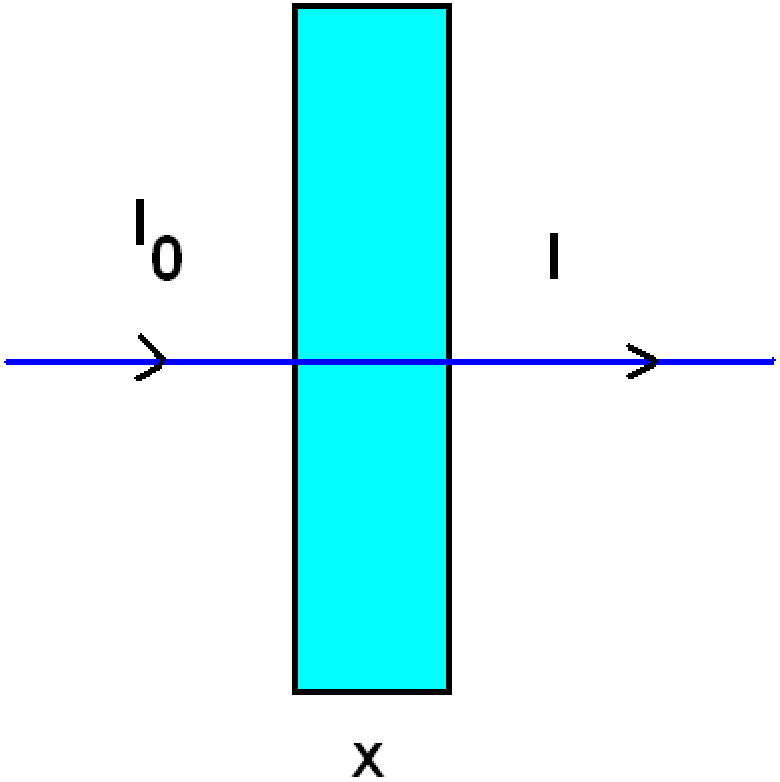


DEVIATION (DEGREES)
INCIDENT ANGLE (DEGREES)
0
30
60
90
α
60°
45°
30°
10°

Transmittance

Light is absorbed while propagating through glass

$$I = I_0 \exp(-\alpha\, x)$$



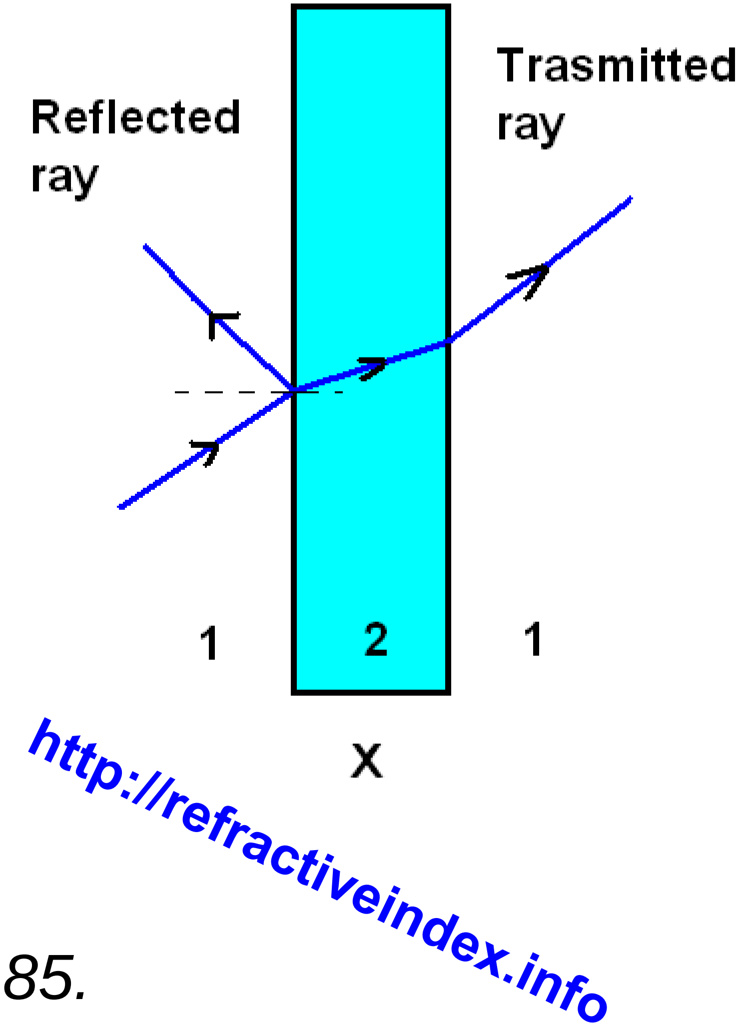
alpha is the absorbtion coefficient.

x is the thinkness of the glass.

Reflection and Transmission

Reflection coeff:

$$R = \frac{(n_1 - n_2)^2}{(n_1 + n_2)^2}$$



For n = 1.5

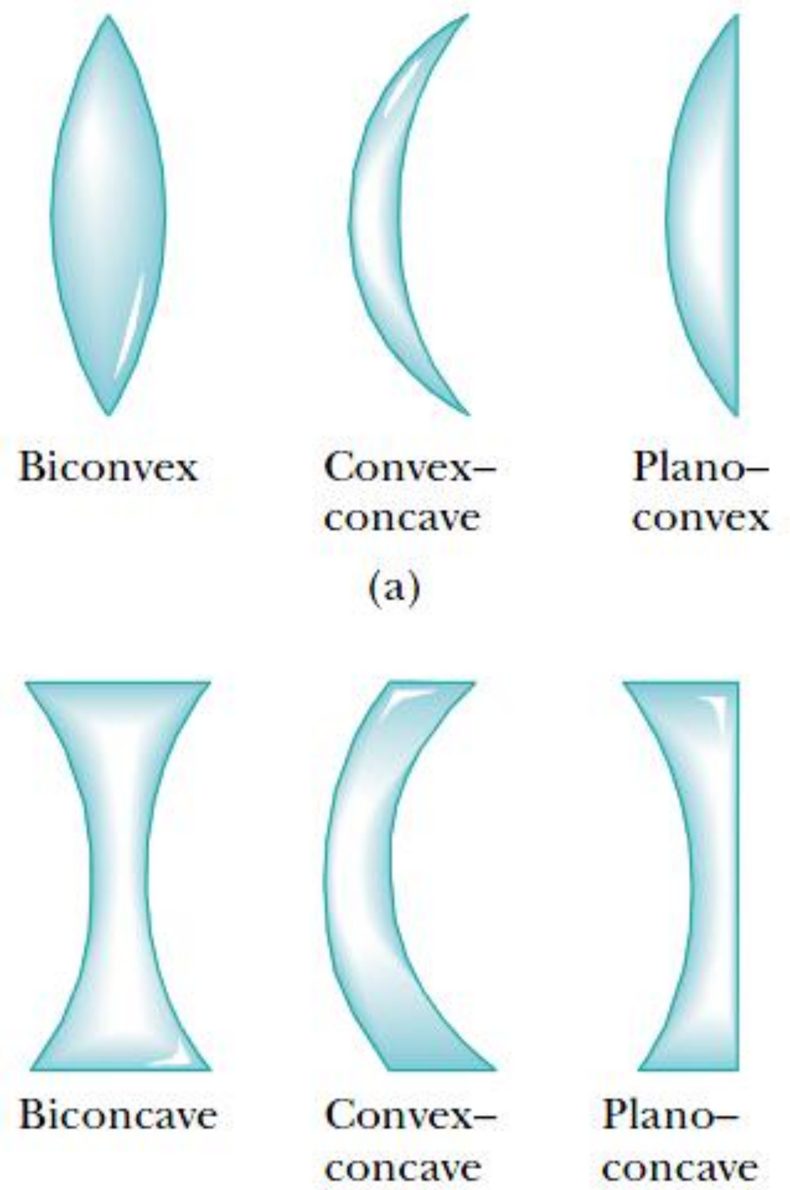
R = 4%

T = 96 %

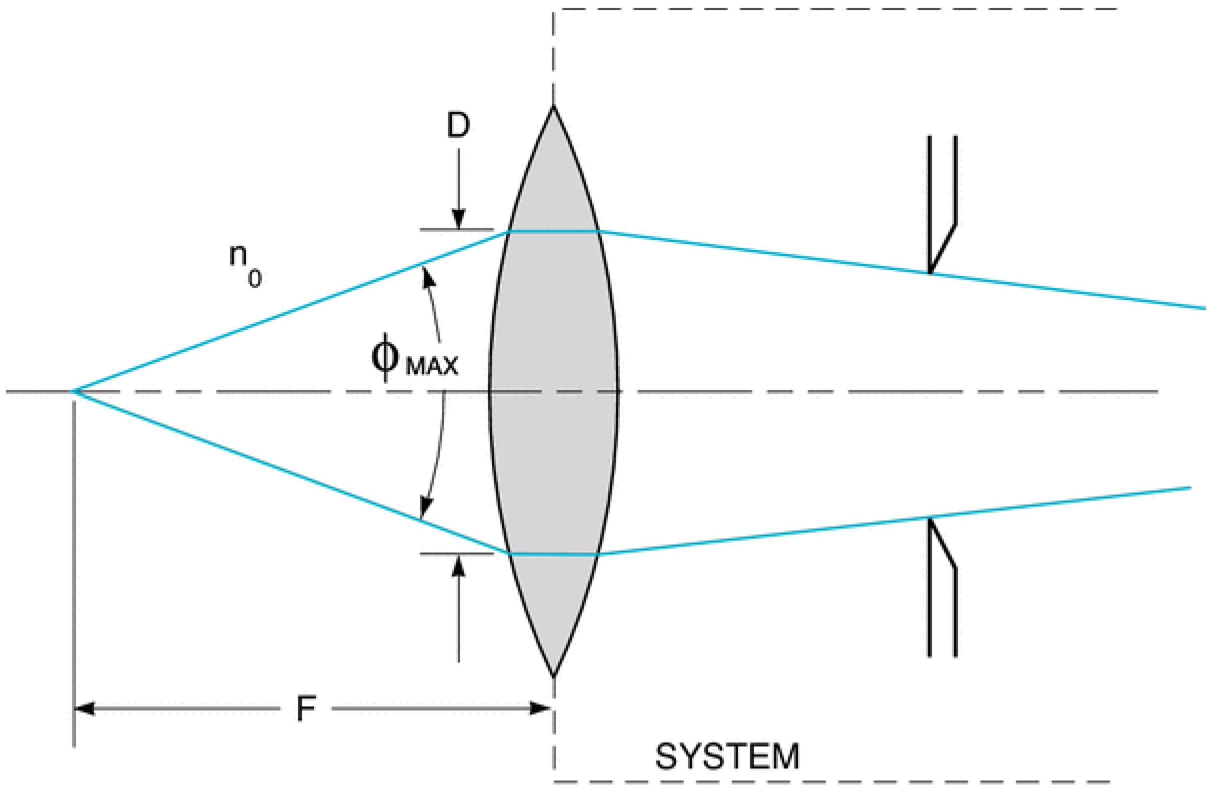
Note: If we use 4 uncoated lenses:

T = (0.96)(0.96)*(0.96)*(0.96) = 0.85.*

Various Lens Shapes



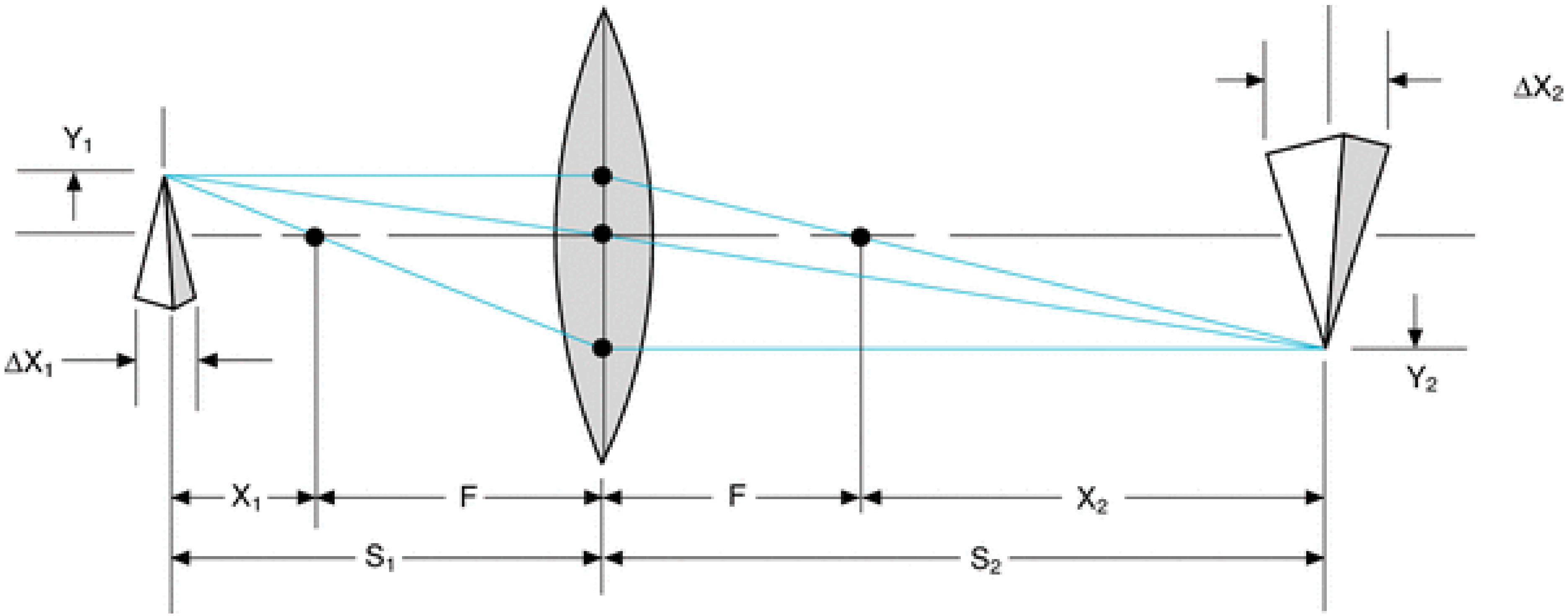
Numerical Aperture



$$NA = n_0 \sin\left(\frac{\phi_{MAX}}{2}\right)$$

$$f/\# = \frac{F}{D} \approx \frac{1}{2\,NA}$$

Thin Lens Equations



$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{F}$$

Tansverse

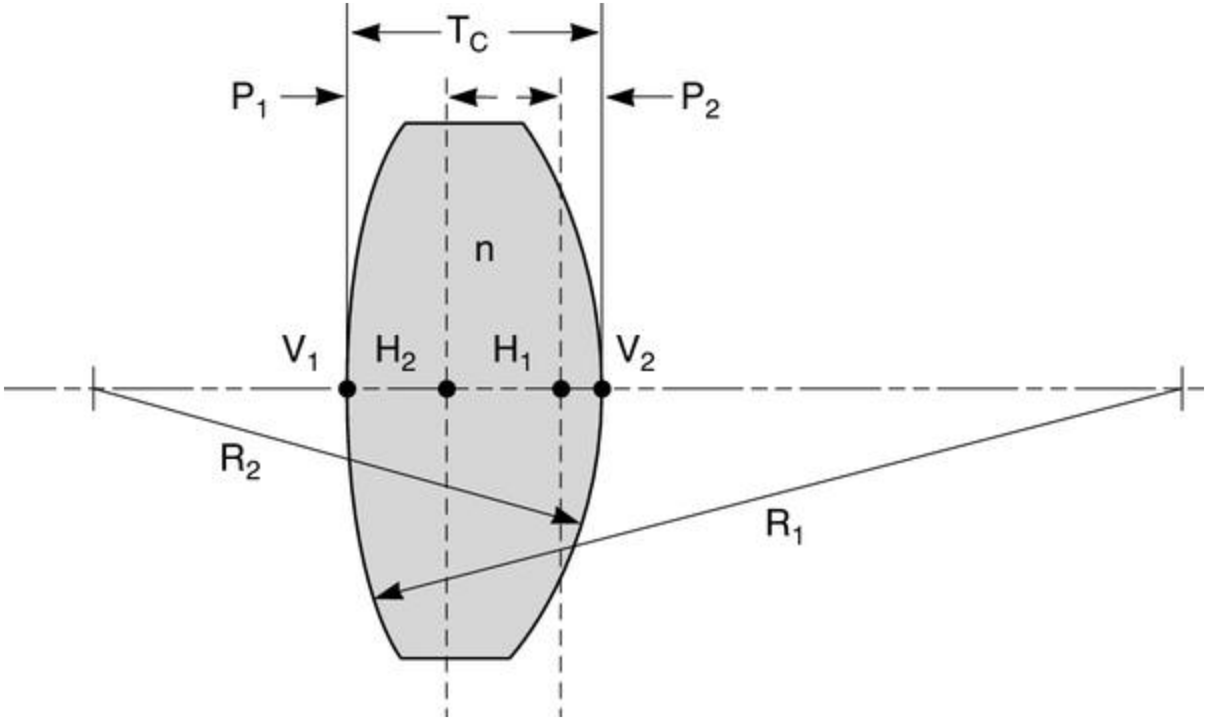
magnification

$$M_T = \frac{y_2}{y_1} = -\frac{S_2}{S_1}$$

Longitidunal magnification

$$M_L = \frac{\Delta x_2}{\Delta x_1} = -M_T^{\ 2}$$

Thick Lens Equations



$$\frac{1}{F} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)T_c}{nR_1R_2}\right]$$

$$P_1 = -\frac{F(n-1)T_c}{nR_2}$$

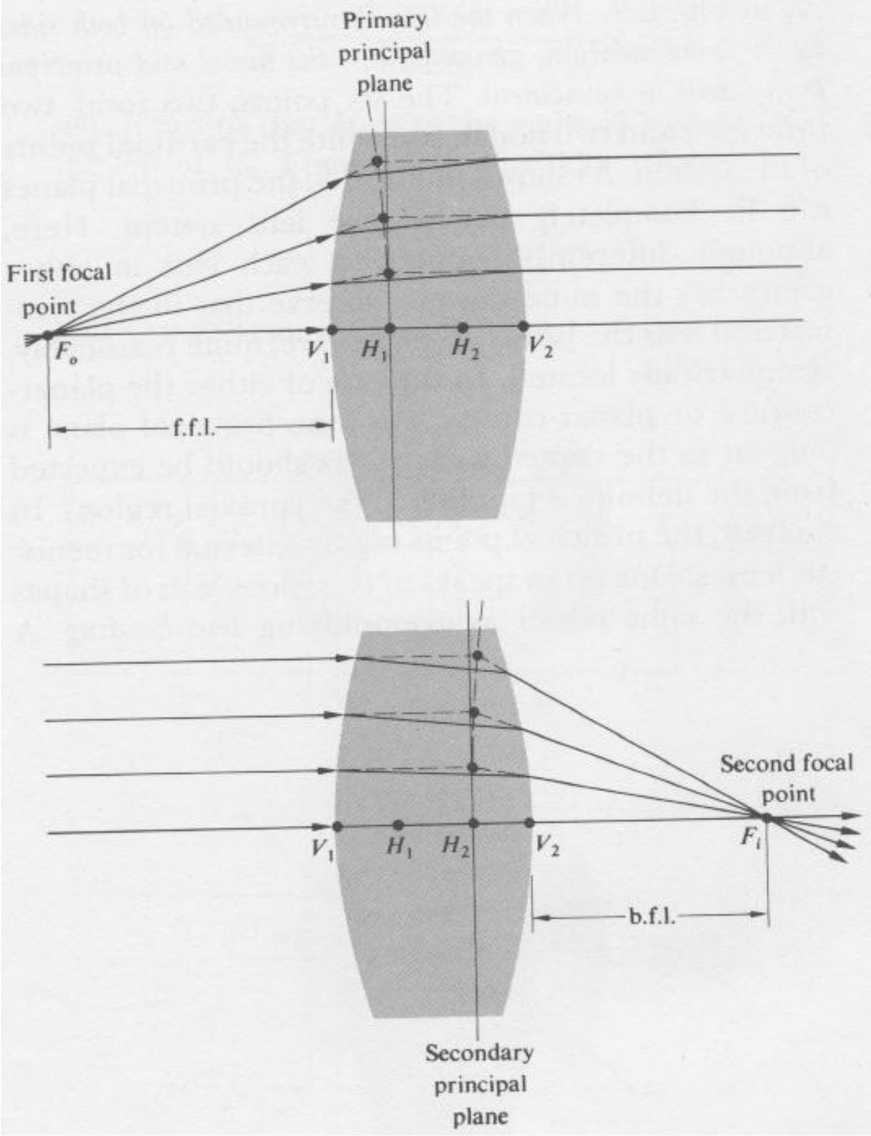
$$P_2 = -\frac{F(n-1)T_c}{nR_1}$$

Thick Lens Equations

f.f.l. = front focal length
b.f.l. = back focal length

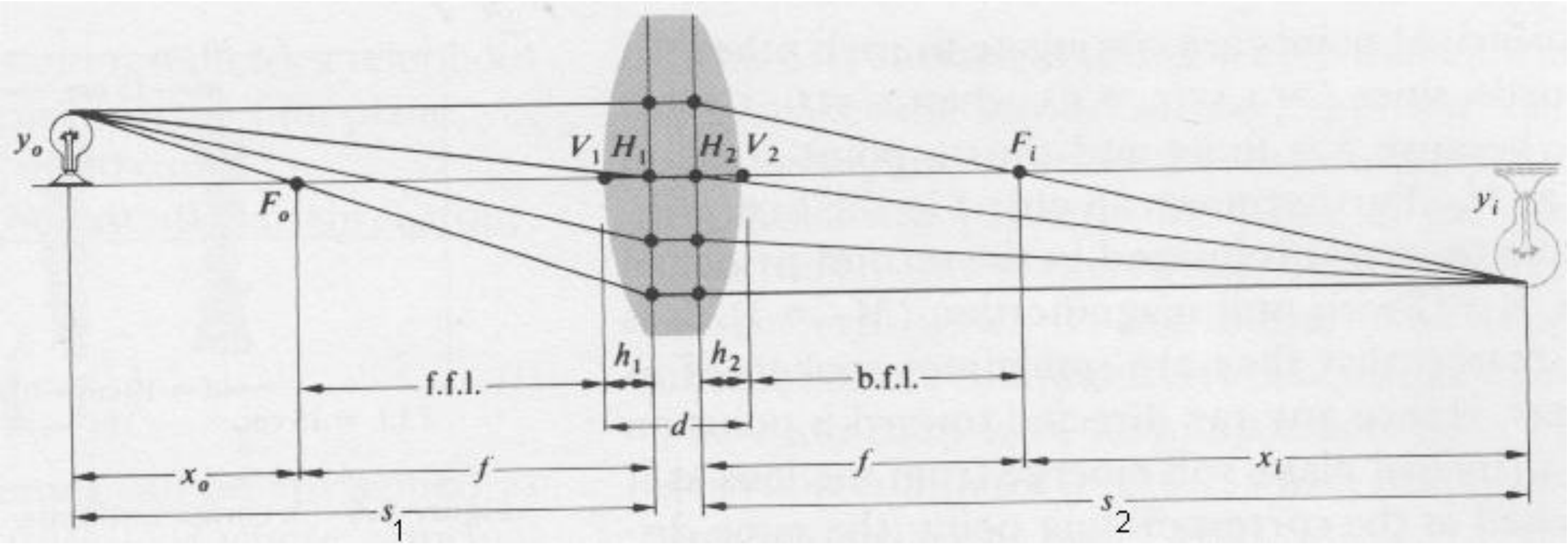
F = Effective Focal Length
measured from H1 or H2

The surface approximating a plane in the paraxial region is termed the principle plane.



Ref: Optics, E. Hecht.

Thick Lens Equations



f = Effective Focal Length
(in ZEMAX EFFL)

Ref: Optics, E. Hecht.