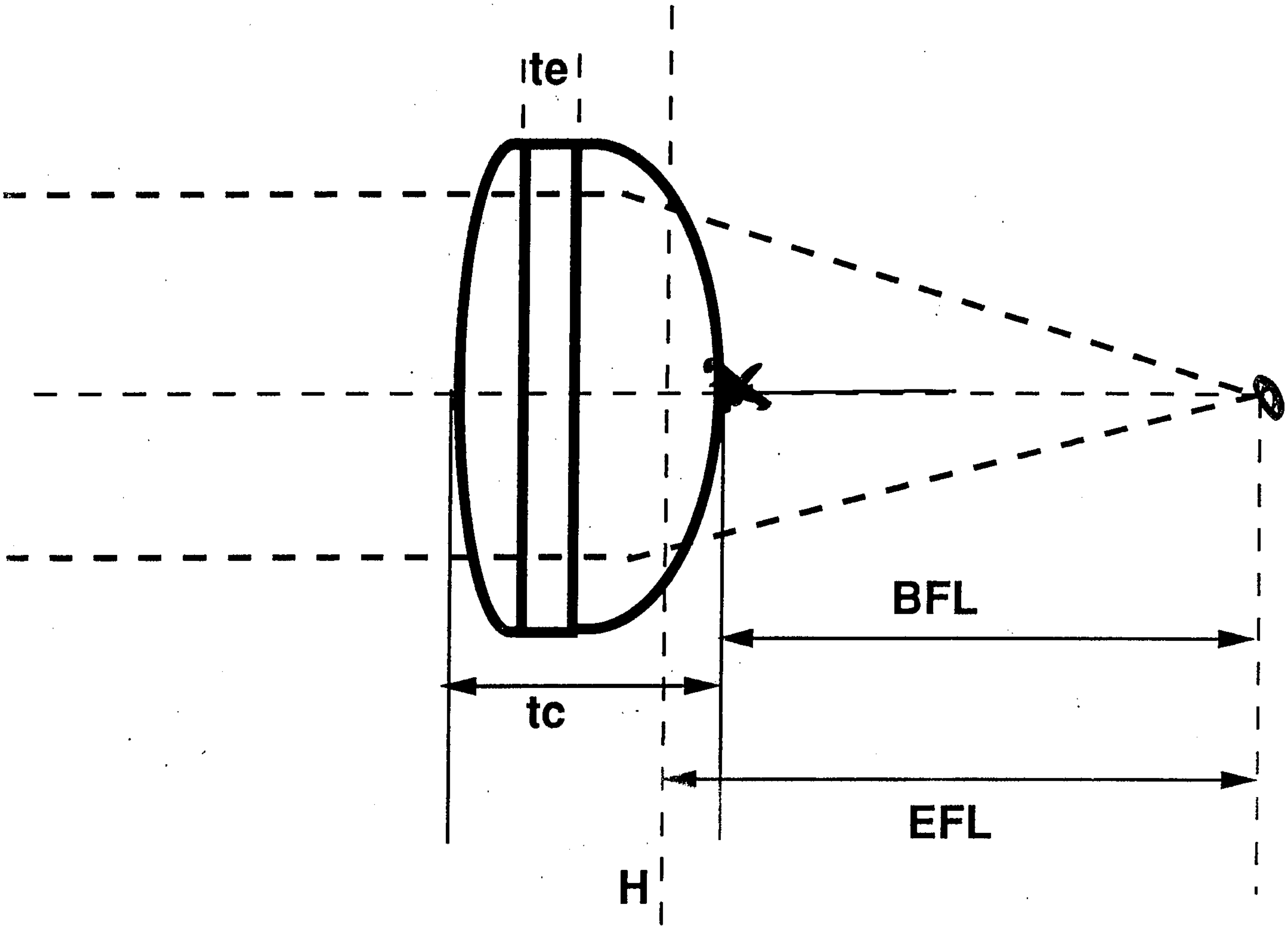
FUNDAMENTAL OPTICS



EFFECTIVE FOCAL LENGTH (EFL)

BACK FOCAL LENGTH (BFL)

CENTER THICKNESS (tc)

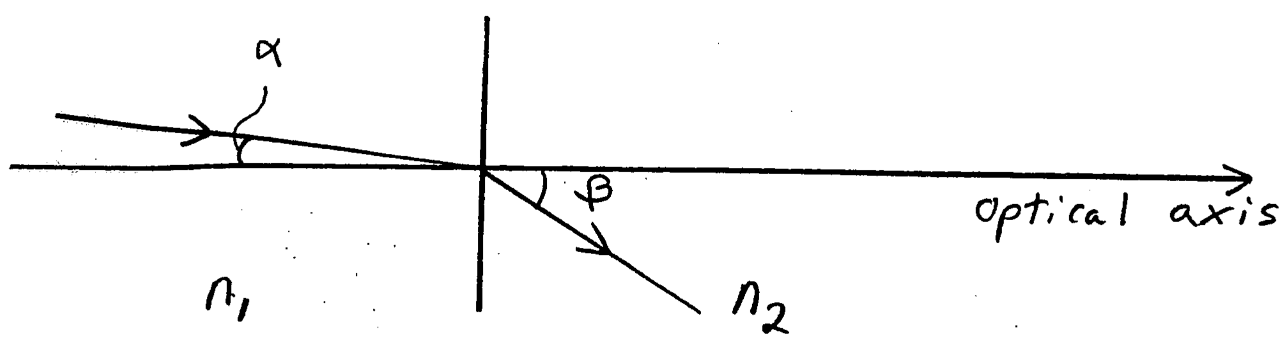
EDGE THICKNESS (te)

PRINCIPAL PLANE (H)

Fundamental Optics

Snell's Law

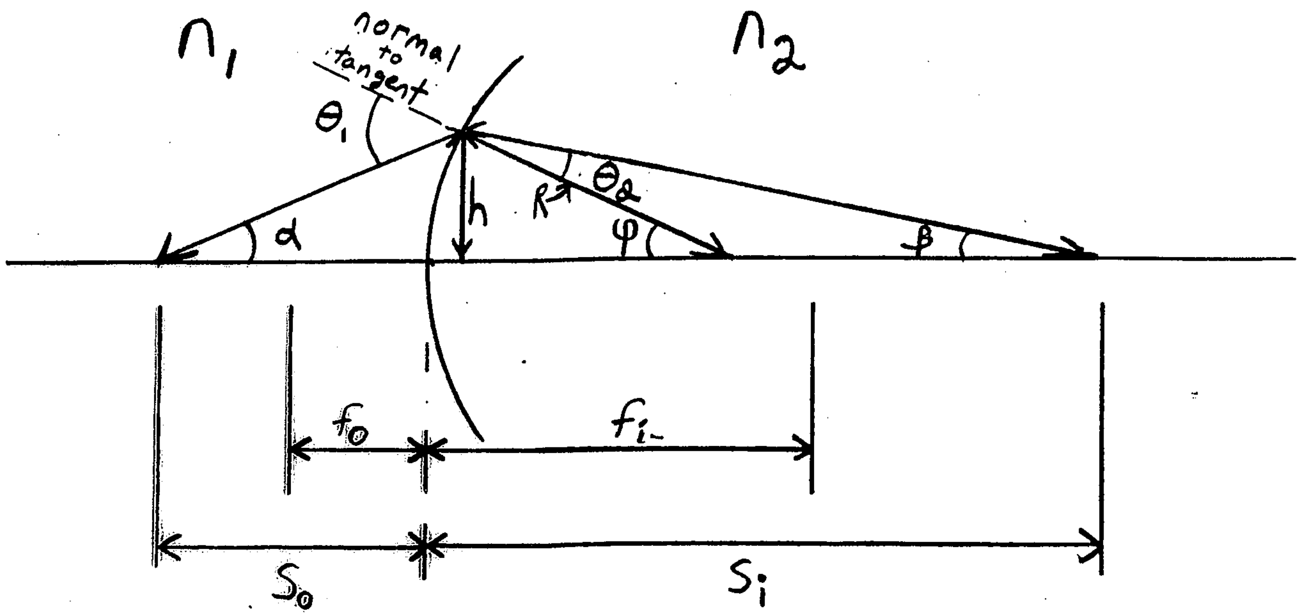
Start with a ray of light crossing an index of refraction interface.



Snell's Law of Refraction states:

$$n_1 \sin\alpha = n_2 \sin\beta$$

Refraction at a Spherical Surface 1/2



R = radius of curvature

n_1 = Object medium index of refraction

n_2 = image medium index of refraction

h = distance from optical axis to ray- lens intersection

f_o = object focal length

f_i = image focal length

S_o = object distance

S_i = image distance

First Order Theory Approximation

Paraxial

1/3

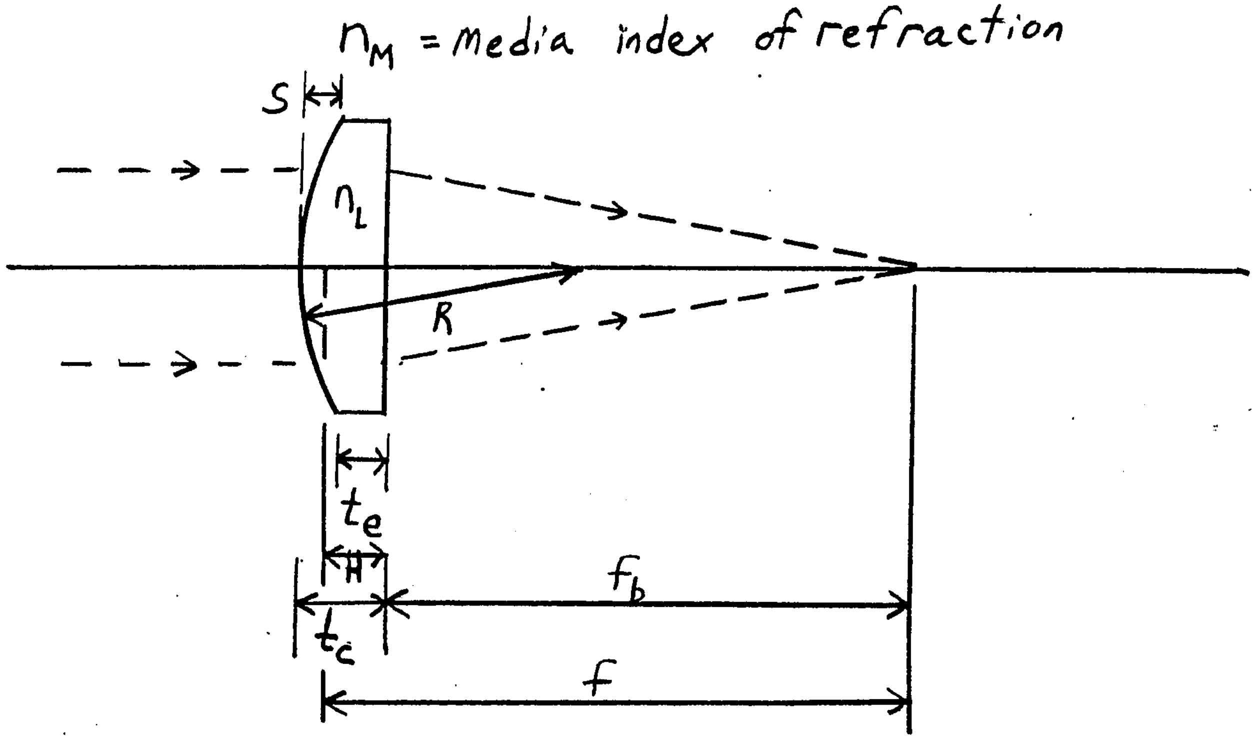
$$\boxed{\sin A = A} - \frac{A^3}{3!} + \frac{A^5}{5!} - \frac{A^7}{7!} + \cdots$$

From Snell's Law and 1^{st} order approx. and the previous diagram.

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

$$\alpha \doteq h/s_o \qquad \beta \doteq h/s_i \qquad \varphi \doteq h/R$$

Plano - Convex Lens



The actual focal length, f, can be measured with incoming parallel rays.

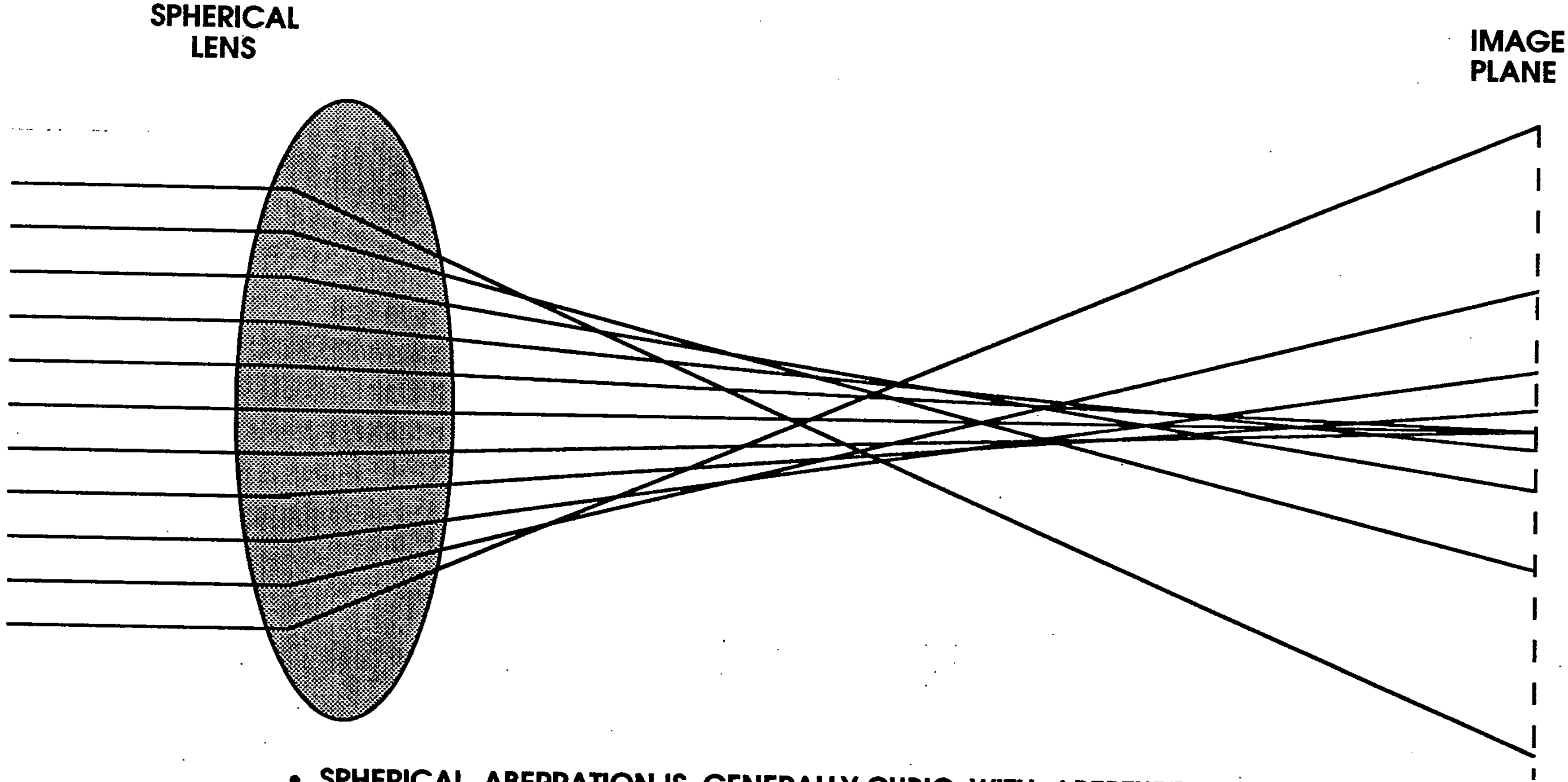
$$f = \frac{n_M R}{(n_L - n_M)}$$ follows from 2

The actual focal power is defined by 2

$$D = \frac{n_M}{f} = \frac{n_L - n_M}{R}$$

$\sin A = A - \frac{A^3}{3!}$

SPHERICAL ABERRATION



- SPHERICAL ABERRATION IS GENERALLY CUBIC WITH APERTURE DIAMETER.
- FOR SPHERICAL LENSES, THE IMAGE QUALITY GOES DOWN WHEN THE APERTURE DIAMETER GOES UP.

BI CONVEX

$$D_{b(air)} = \frac{1}{BFL_{air}} = \frac{1}{EFL_{air}\left(1 - \frac{T_c\left(n_l - n_{air}\right)}{n_l R_a}\right)}$$

$$EFL_{air} = \frac{BFL_{air}}{\left(1 - \frac{T_c\left(n_l - n_{air}\right)}{n_l R_a}\right)}$$

$$D_{air} = \frac{n_{air}}{EFL_{air}}$$

$$D_{aq} = \frac{\left(n_l - n_{aq}\right)\left(\left(R_p - R_a\right)n_l + \left(n_l - n_{aq}\right)T_c\right)}{\left(n_l - n_{air}\right)\left(\left(R_p - R_a\right)n_l + \left(n_l - n_{air}\right)T_c\right)} D_{air}$$

$$T_c = T_e + \left(R_a + \left|R_p\right|\right) - \sqrt{R_a^2 - \left(\frac{d_a}{2}\right)^2} - \sqrt{R_p^2 - \left(\frac{d_p}{2}\right)^2}$$

3rd Order Spherical Aberration:

SA at S1 = -0.00101693
SA at S2 = -0.0650685
SAsum = -0.0660854

Focus Shift Results:

First Order BFL = 10.5817

delta Z = -0.333992

New BFL w/Focus Shift= 10.2477

For lens shapes other than plano-convex, the conversion to power <u>in situ</u> from power in air is more complicated. It requires solving the lens equation for the unknown radius of curvature, followed by replacement of the index of refraction values used in air with those appropriate to <u>in situ</u>. Table A2.1 provides example ratios of power <u>in situ</u> to power in air calculated for a variety of lens shapes. These ratios represent paraxial to paraxial solutions. An observer measuring focal length will most likely choose a focal plane slightly closer to the lens than paraxial due to the effects of spherical aberration. The magnitude of this shift was estimated by MTF calculations from ray-trace analysis and is also shown in Table I. It may be necessary to incorporate this shift into the conversion ratio in order to maintain the required tolerance of labeled power.

ANSI Z80.7 1992