PHYS 3038 Optics
L5 Geometrical Optics
Reading: Ch5.1-5.3

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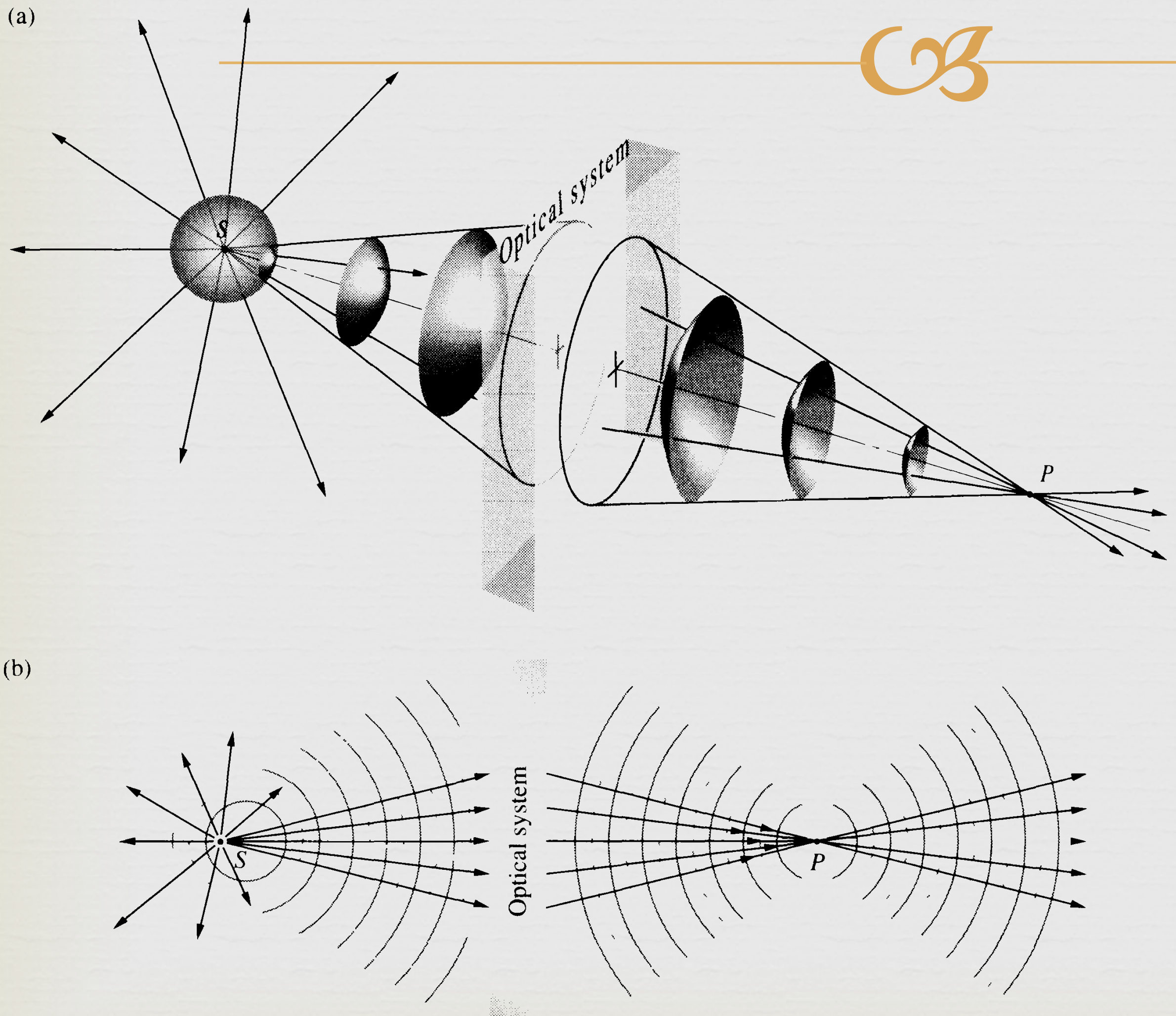
2015, the Year of Light

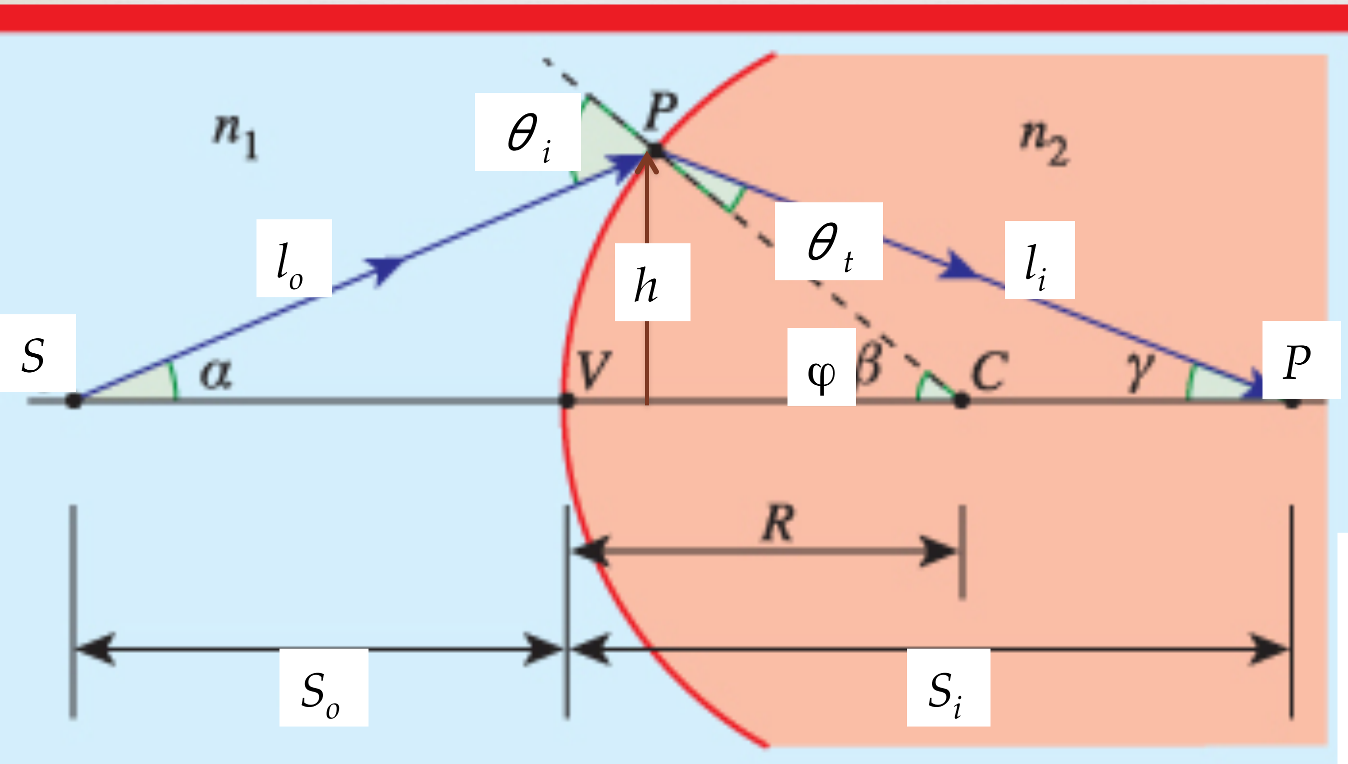
Ray Optics



$\lambda \rightarrow 0$

Figure 5.1 Conjugate foci. (*a*) A point source *S* sends out spherical waves. A cone of rays enters an optical system that inverts the wavefronts, causing them to converge on point *P*. (*b*) In cross section rays diverge from *S*, and a portion of them converge to *P*. If nothing stops the light at *P*, it continues on.

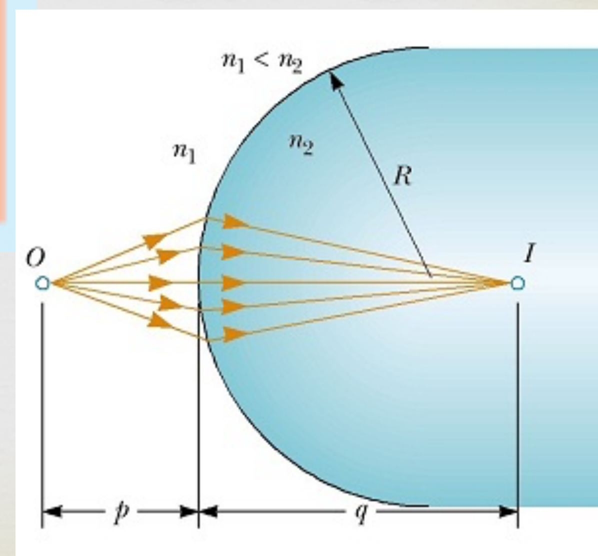
5.2.2 Refraction at Spherical Surfaces



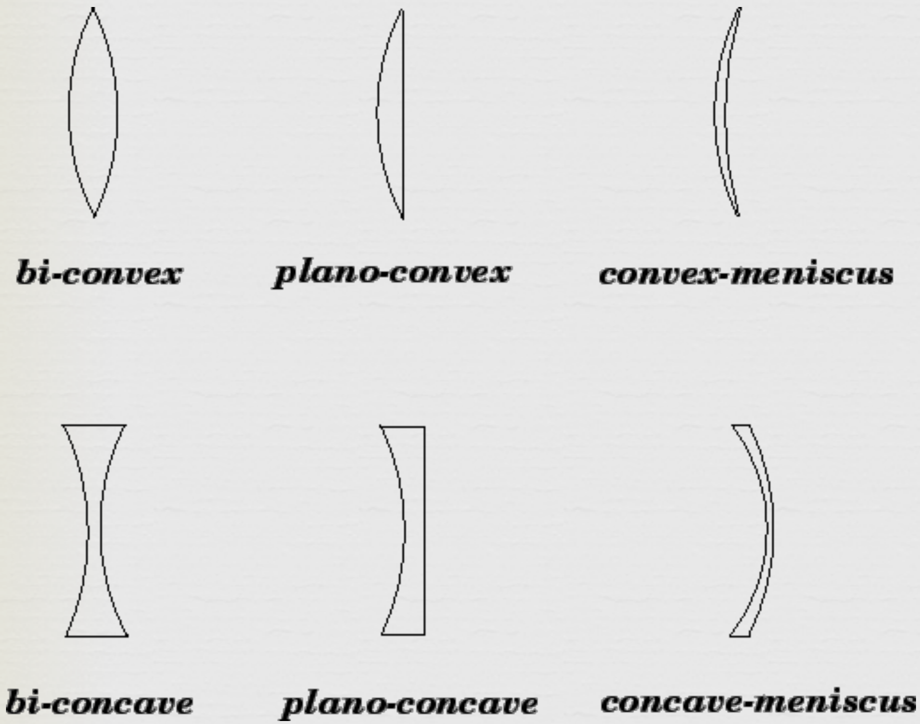
Paraxial rays

$$\sin\varphi \approx \varphi$$

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$

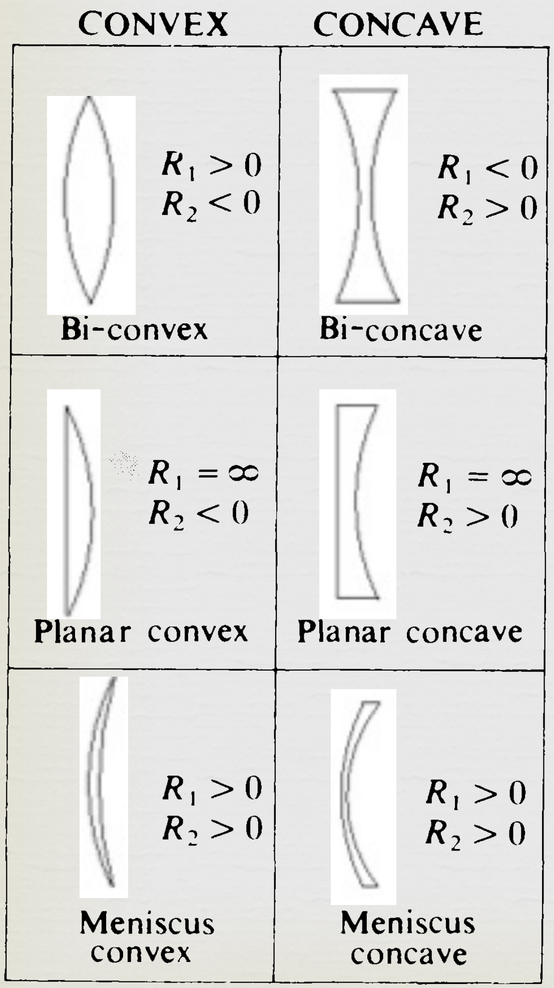


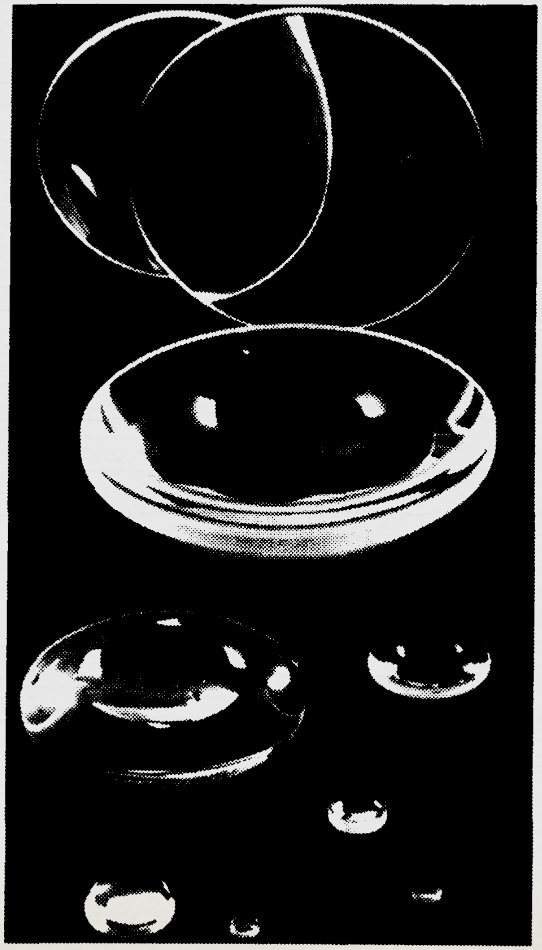
5.2.3 Thin Lens



$$\frac{1}{s_o} + \frac{1}{s_i} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f}$$

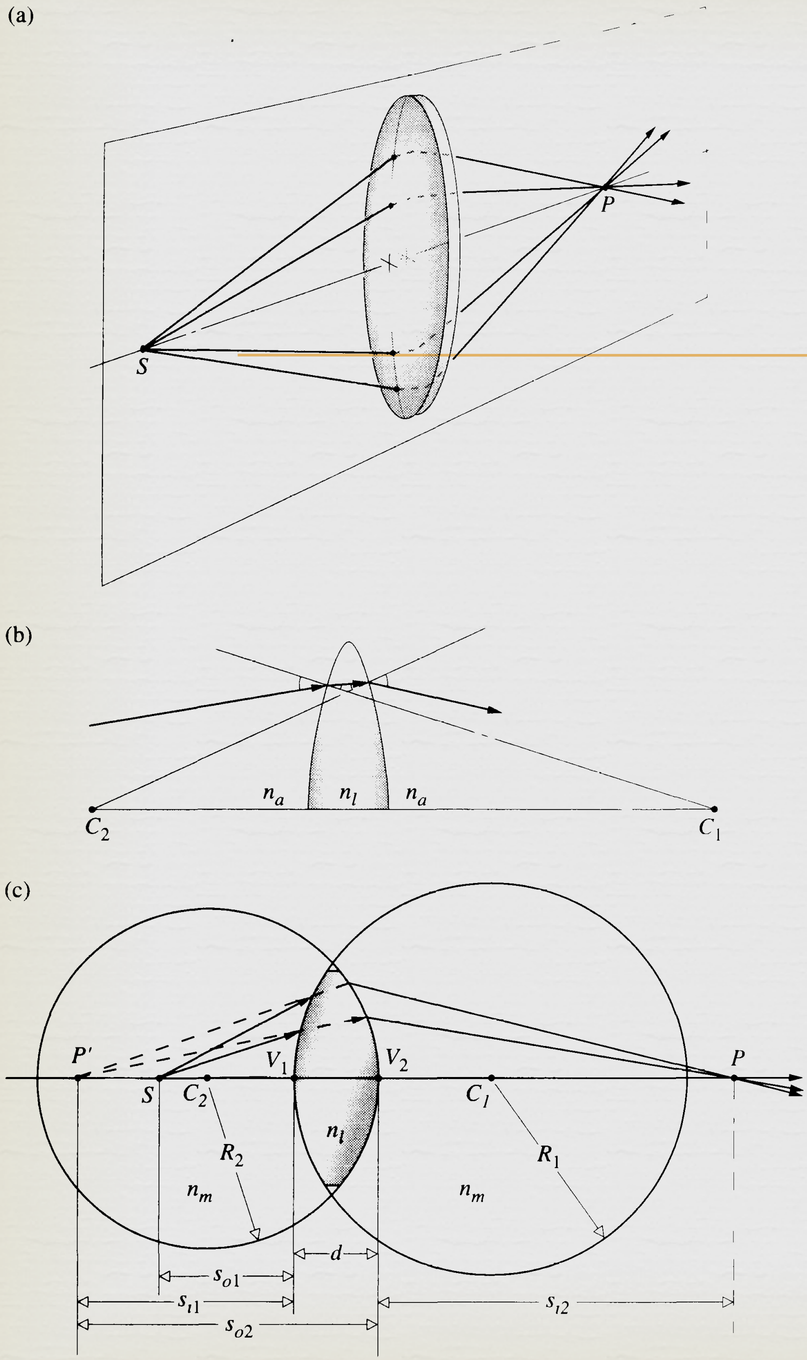
Thin Lens





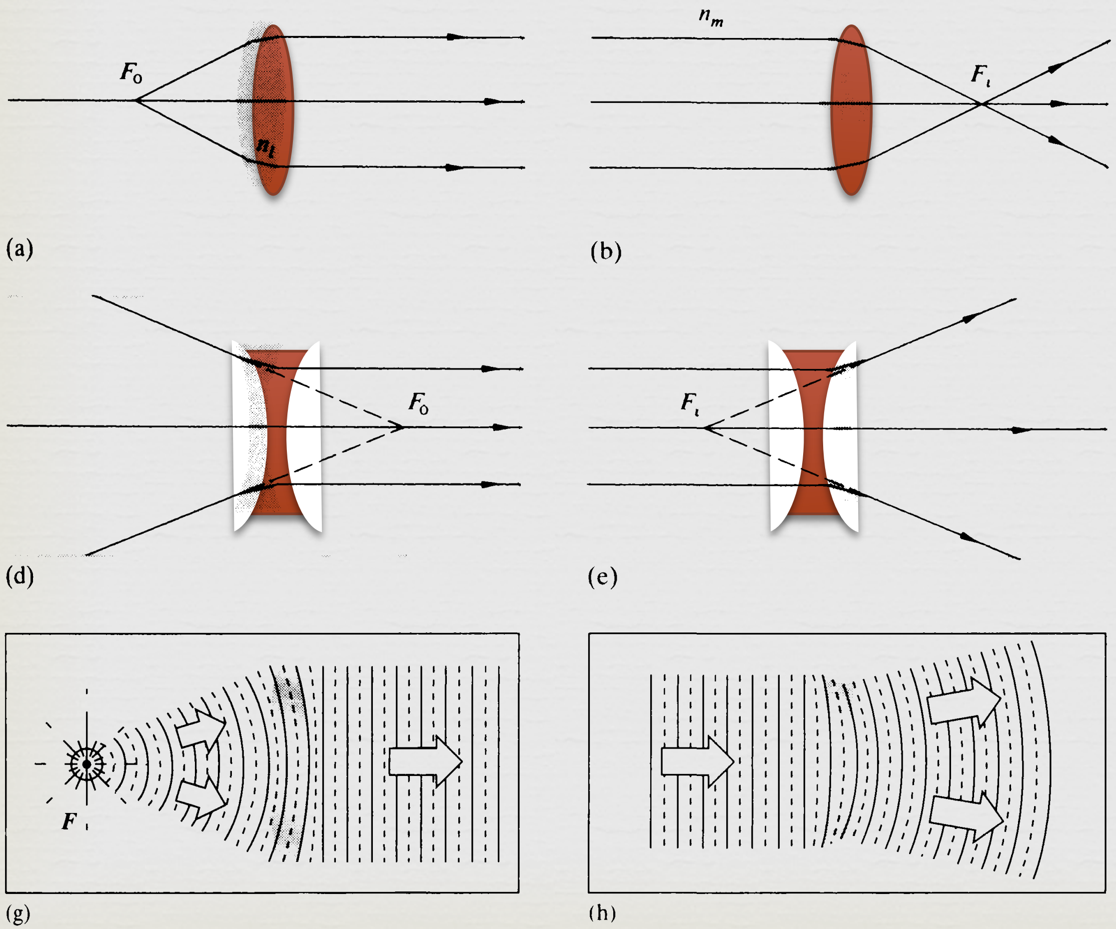
$$\frac{1}{s_o}+\frac{1}{s_i}=(n_l-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\frac{1}{f}$$

A Spherical Lens



$$\frac{1}{s_o}+\frac{1}{s_i}=(n_l-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\frac{1}{f}$$

Focal Points

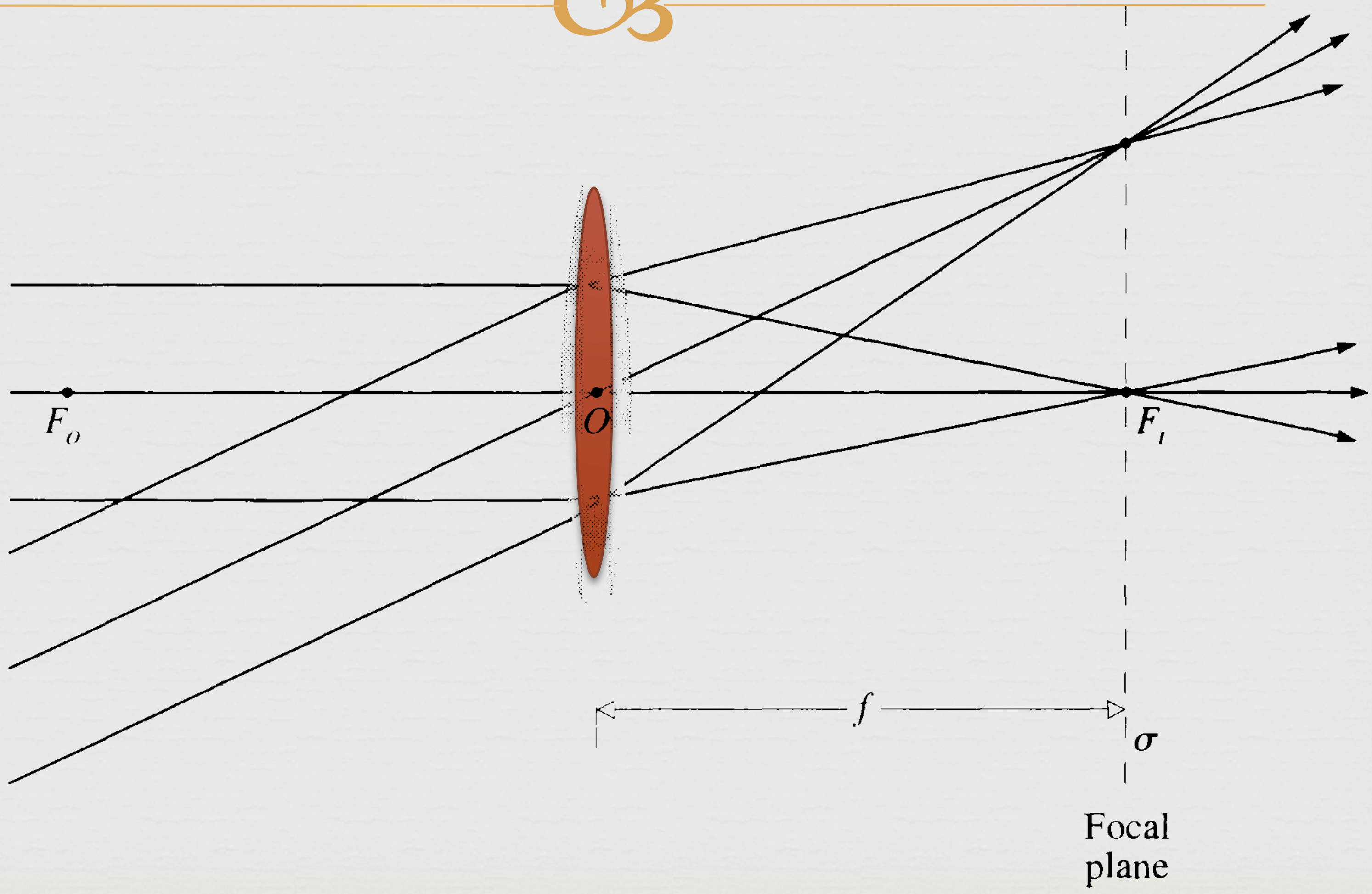


Positive lens f > 0

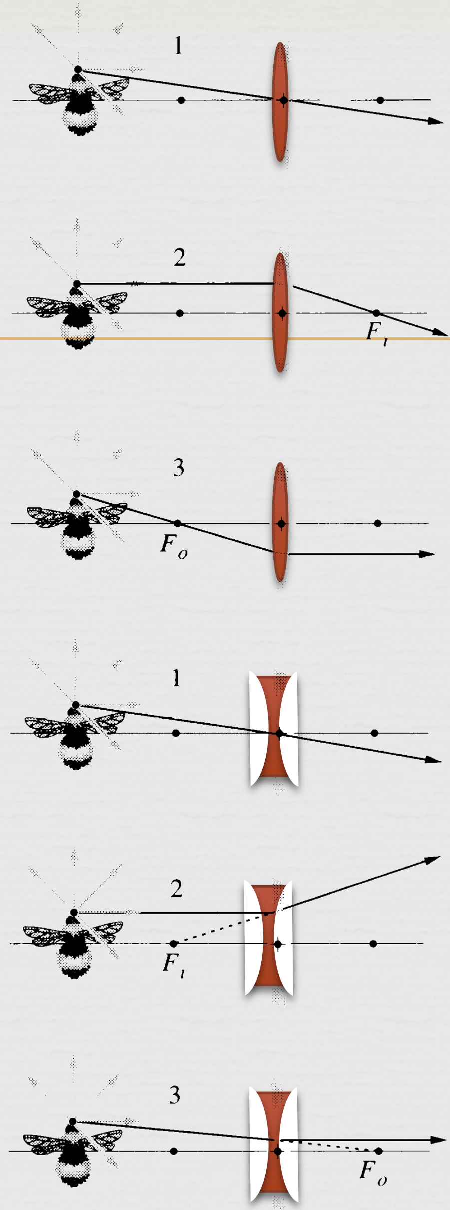
Negative lens f < 0

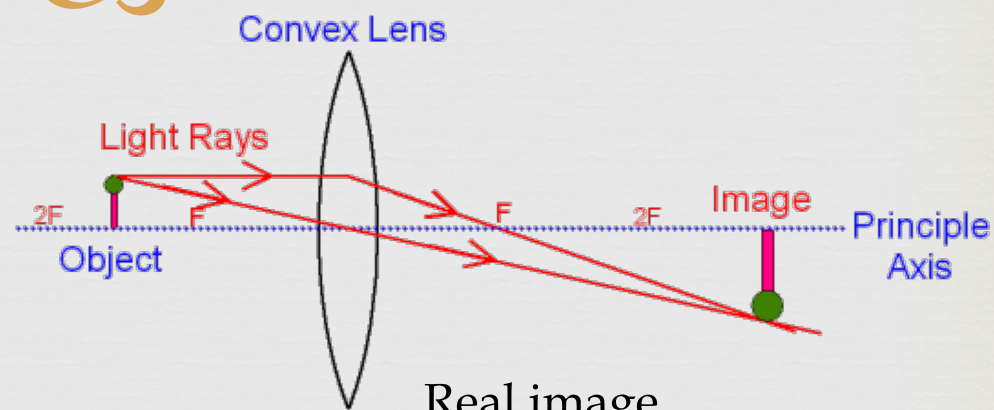
$$\frac{1}{f} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Focal Plane

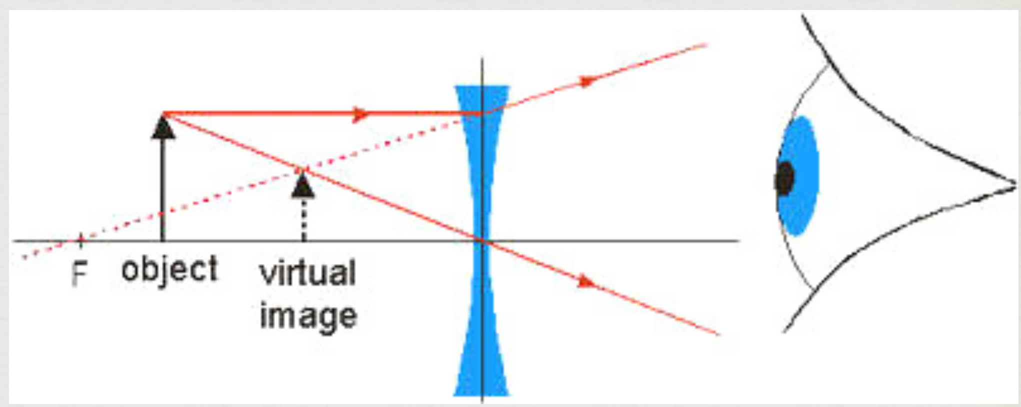


Finite Imagery





Real image

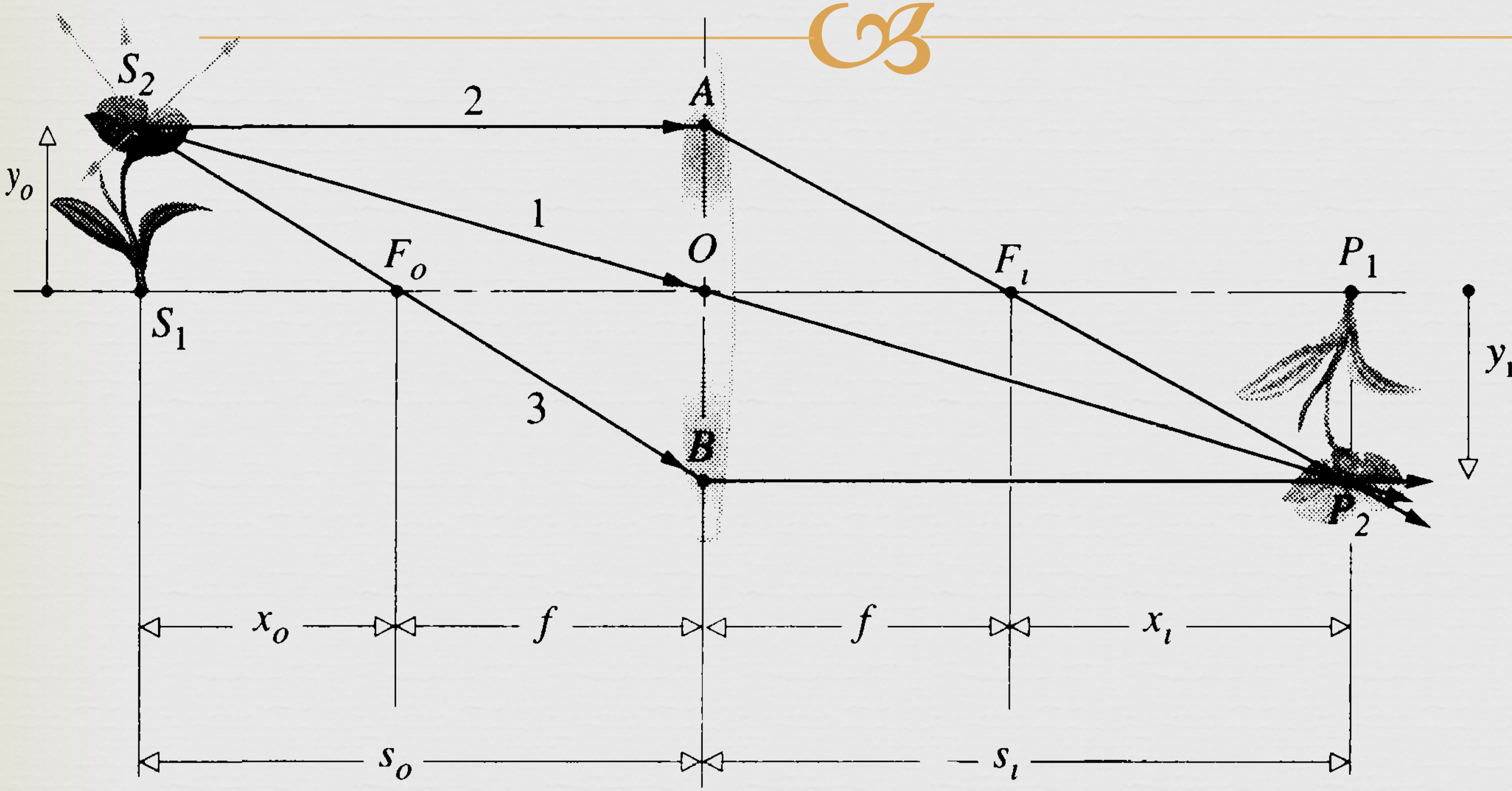


Imaginary image

Object and Image

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$

$$x_o x_i = f^2$$



Transverse Magnification

$$M_T=\frac{y_i}{y_o}=-\frac{s_i}{s_0}=-\frac{x_i}{f}=-\frac{f}{x_o}$$

TABLE 5.2 Meanings Associated with the Signs of Various Thin Lens and Spherical Interface Parameters

Quantity	Sign +	Sign −
s_o	Real object	Virtual object
s_i	Real image	Virtual image
f	Converging lens	Diverging lens
y_o	Erect object	Inverted object
y_i	Erect image	Inverted image
M_T	Erect image	Inverted image

TABLE 5.3 Images of Real Objects Formed by Thin Lenses

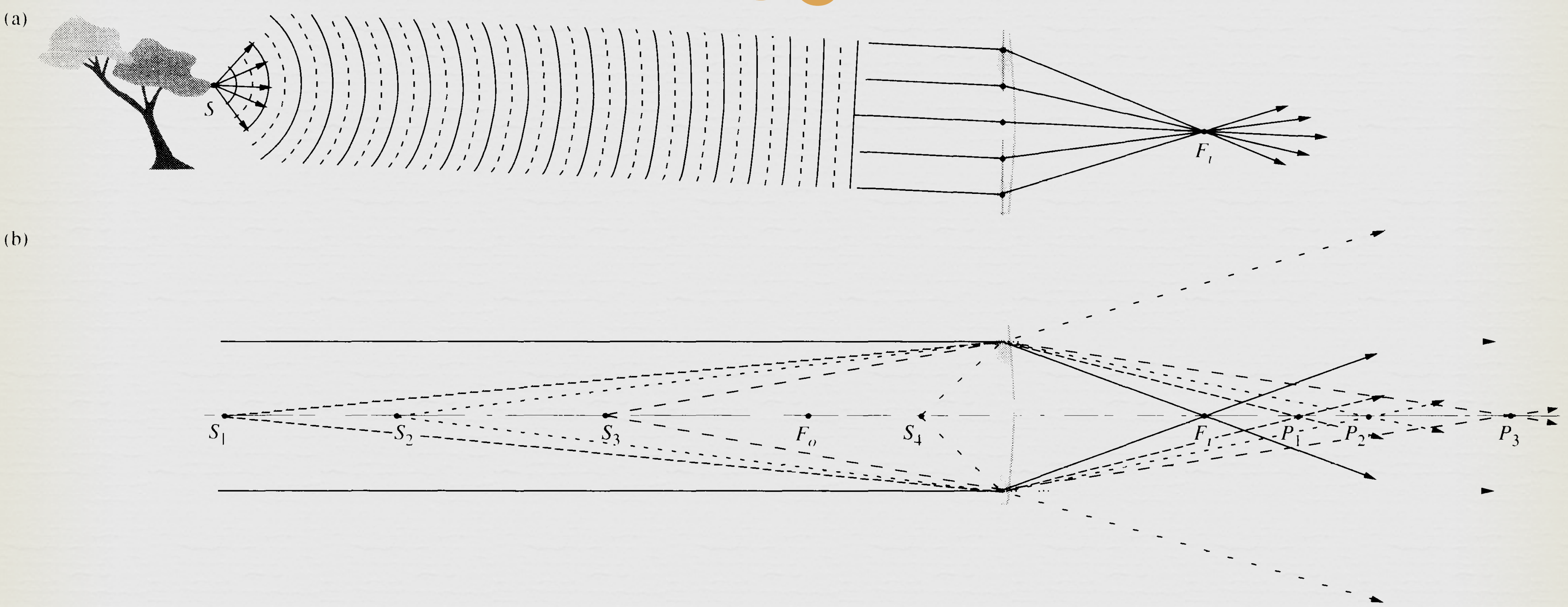
Convex

Object	Image			
Location	Type	Location	Orientation	Relative Size
$\infty > s_o > 2f$	Real	$f < s_i < 2f$	Inverted	Minified
$s_o = 2f$	Real	$s_i = 2f$	Inverted	Same size
$f < s_o < 2f$	Real	$\infty > s_i > 2f$	Inverted	Magnified
$s_o = f$		$\pm\infty$		
$s_o < f$	Virtual	$\|s_i\| > s_o$	Erect	Magnified

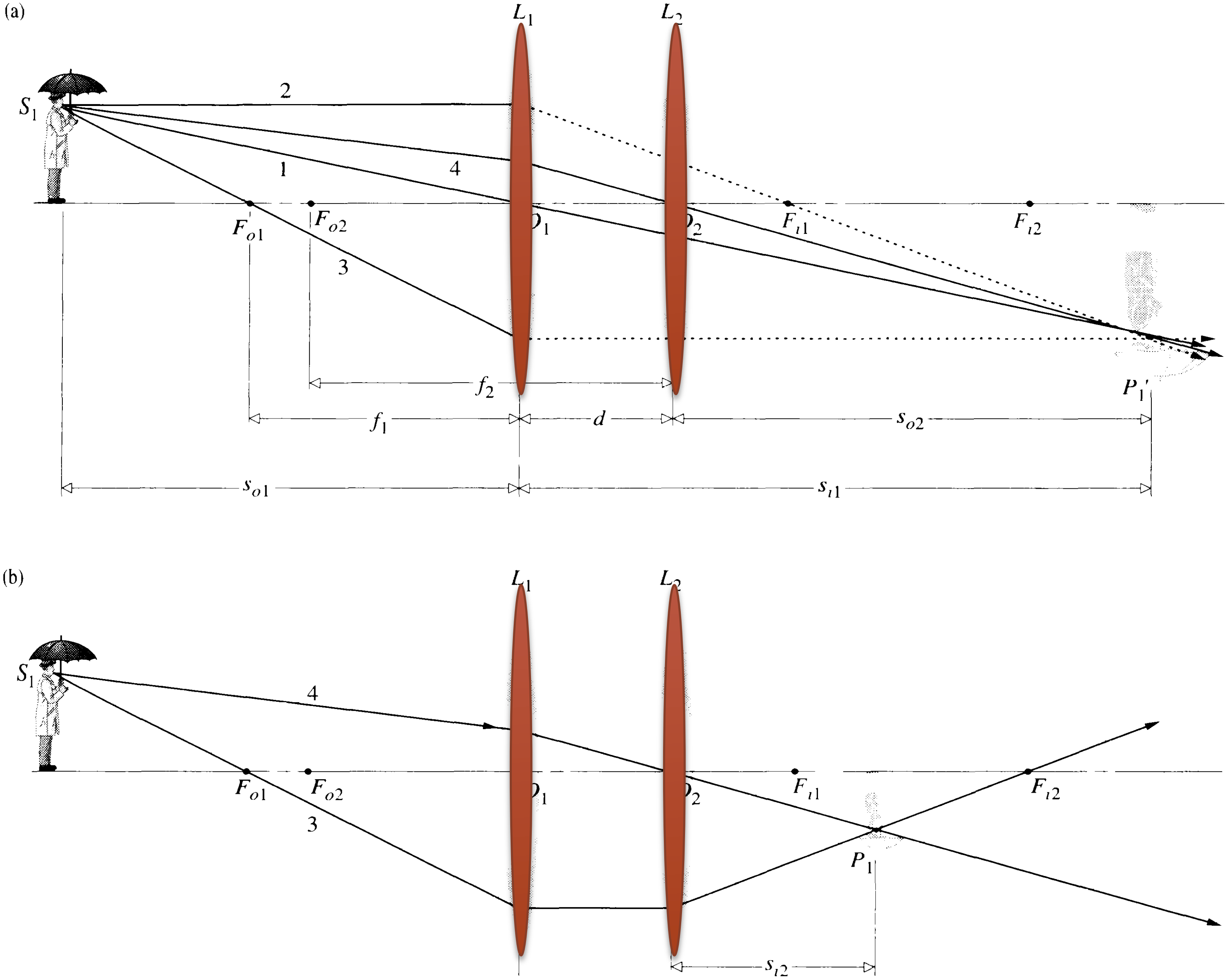
Concave

Object	Image			
Location	Type	Location	Orientation	Relative Size
Anywhere	Virtual	$\|s_i\| < \|f\|$, $s_o > \|s_i\|$	Erect	Minified

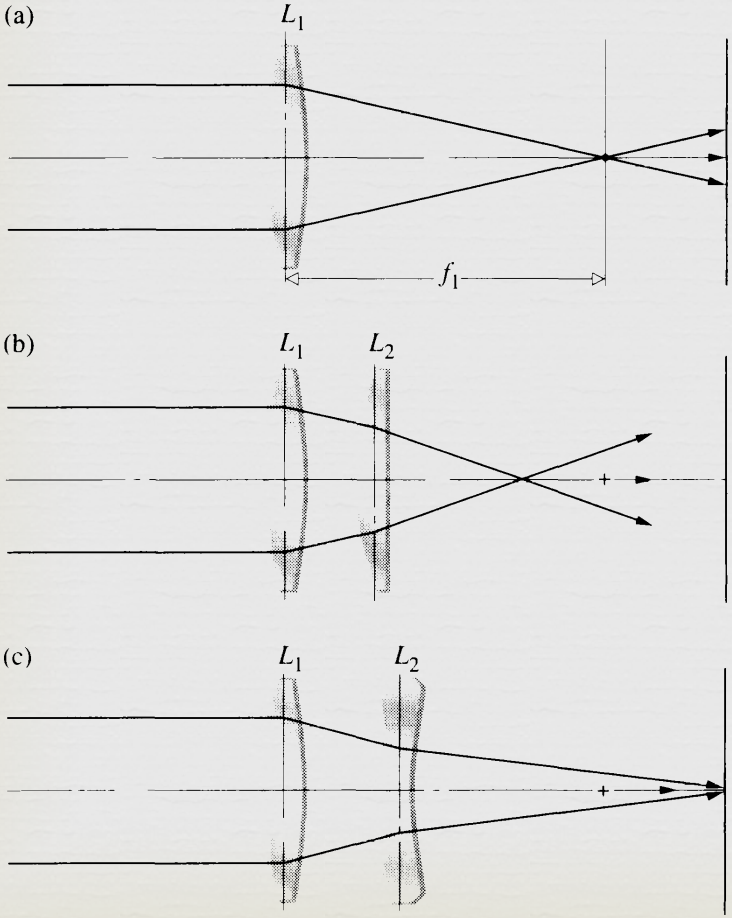
Longitudinal Magnification



$$M_L = \frac{dx_i}{dx_o} = -\left(\frac{f}{x_o}\right)^2 = -M_T^2$$


(a)
L1
L2
S1
2
1
4
F'o1
Fo2
O1
O2
Fi1
Fi2
3
P1'
f2
f1
d
so2
so1
si1
(b)
L1
L2
S1
4
Fo1
Fo2
O1
O2
Fi1
Fi2
3
P1
si2

Front and Back Focal Lengths



$$\text{f.f.l.} = \frac{f_1(d - f_2)}{d - (f_1 + f_2)}$$

$$\text{b.f.l.} = \frac{f_2(d - f_1)}{d - (f_1 + f_2)}$$

As d=0

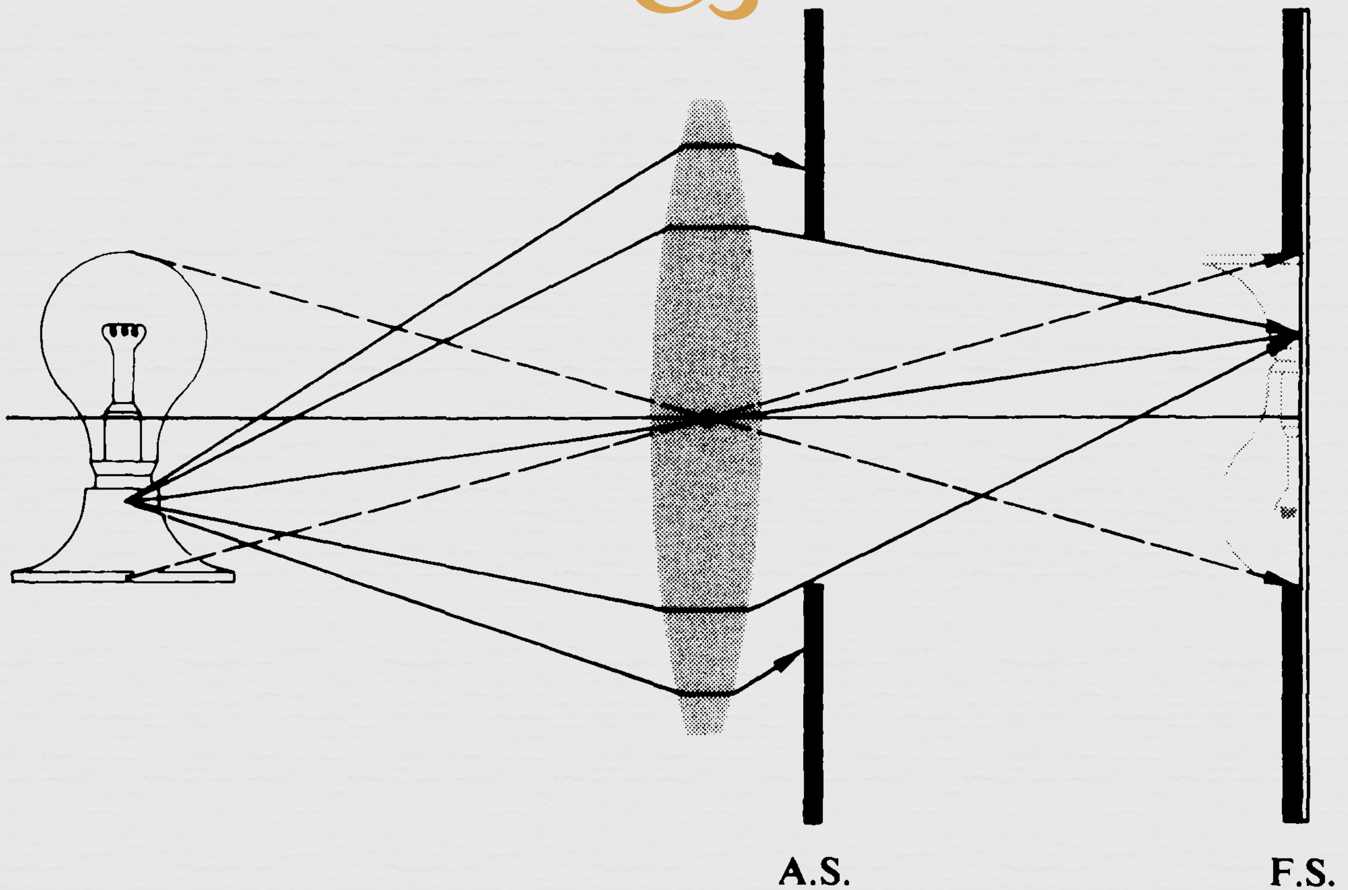
$$\text{b.f.l.} = \text{f.f.1.} = \frac{f_2 f_1}{f_2 + f_1}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \cdots + \frac{1}{f_N}$$

Lens Combination: Profesional Camera Lens

5.3.1 Aperture Stop and Field Stop



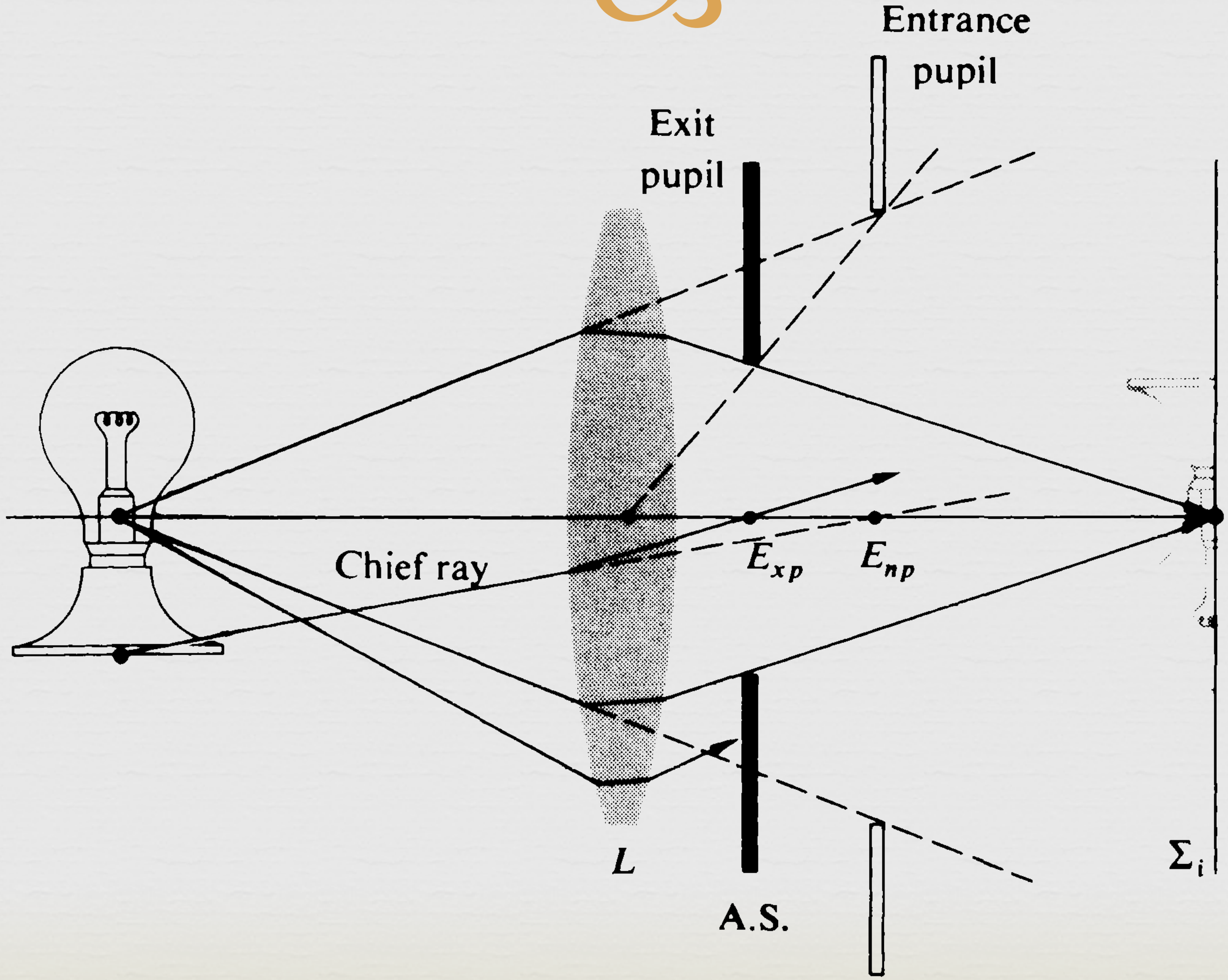
Field of view of the instrument

5.3.2 Entrance & Exit Pupils

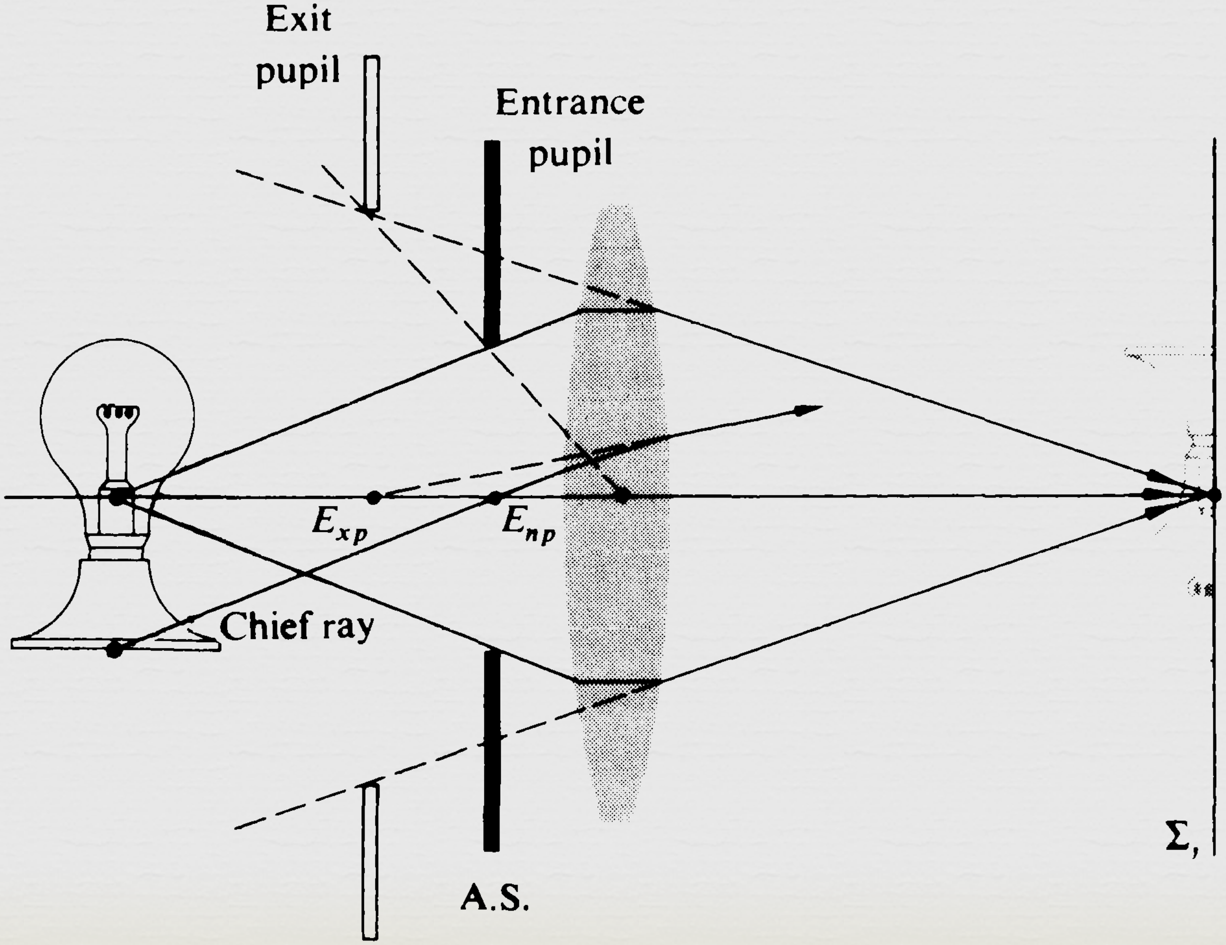
- **Entrance Pupil** of a system is the **image of the aperture stop (A.S.) as seen from an axial point on the object through those elements preceding the stop**.

- **Exit Pupil** is the **image of the A.S. as seen from an axial point on the image plane through the interposed lenses, if there are any**.

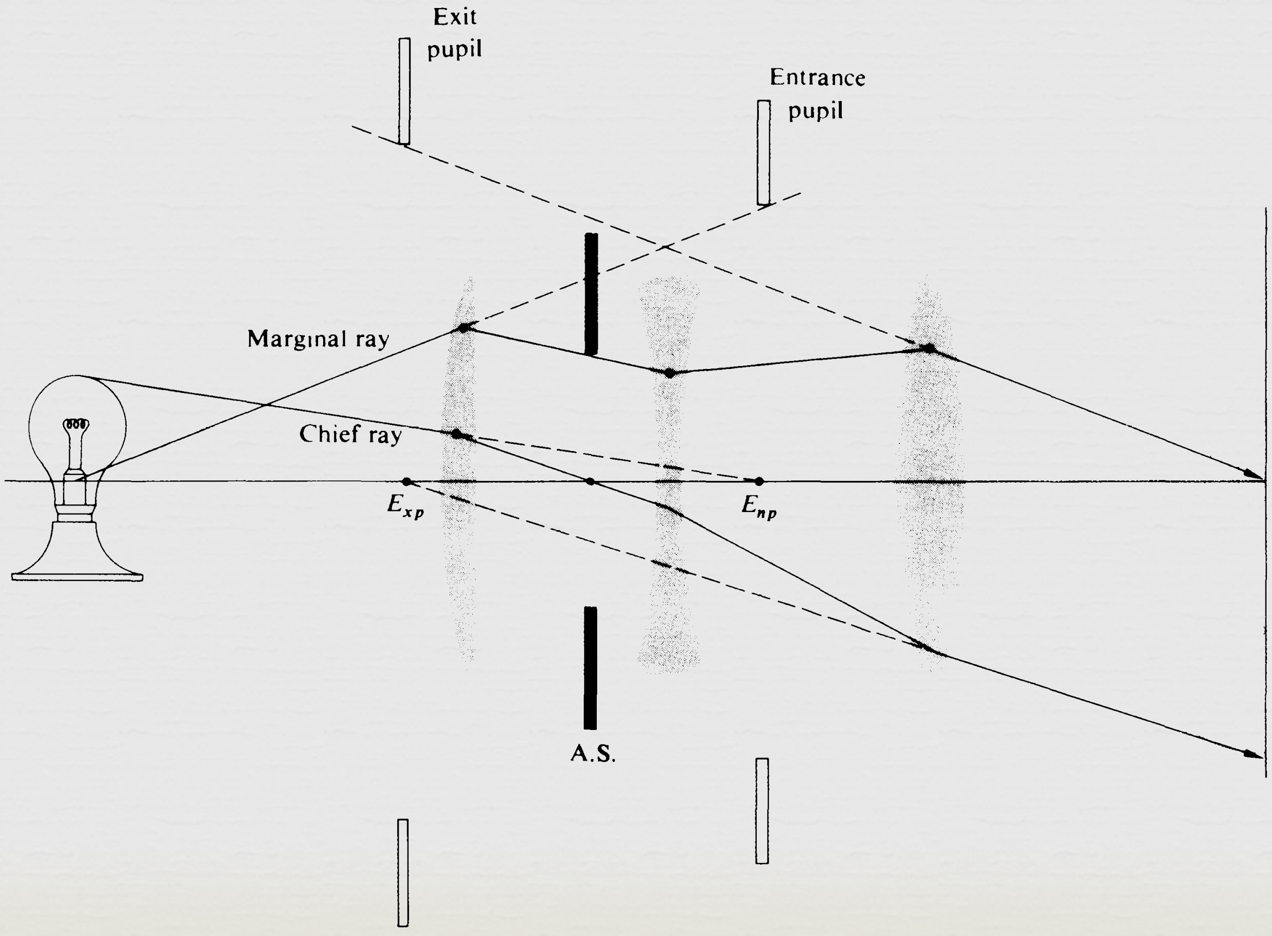
Entrance & Exit Pupils



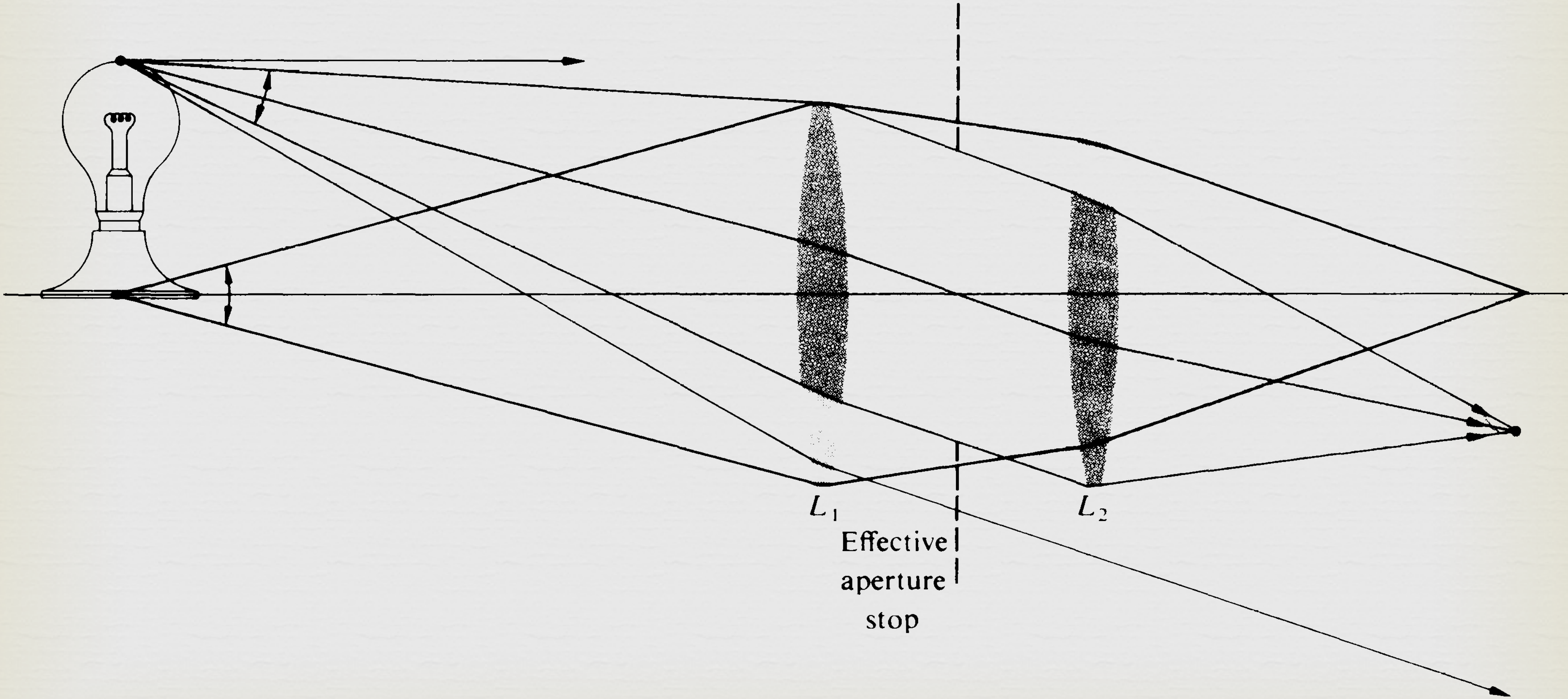
Entrance & Exit Pupils



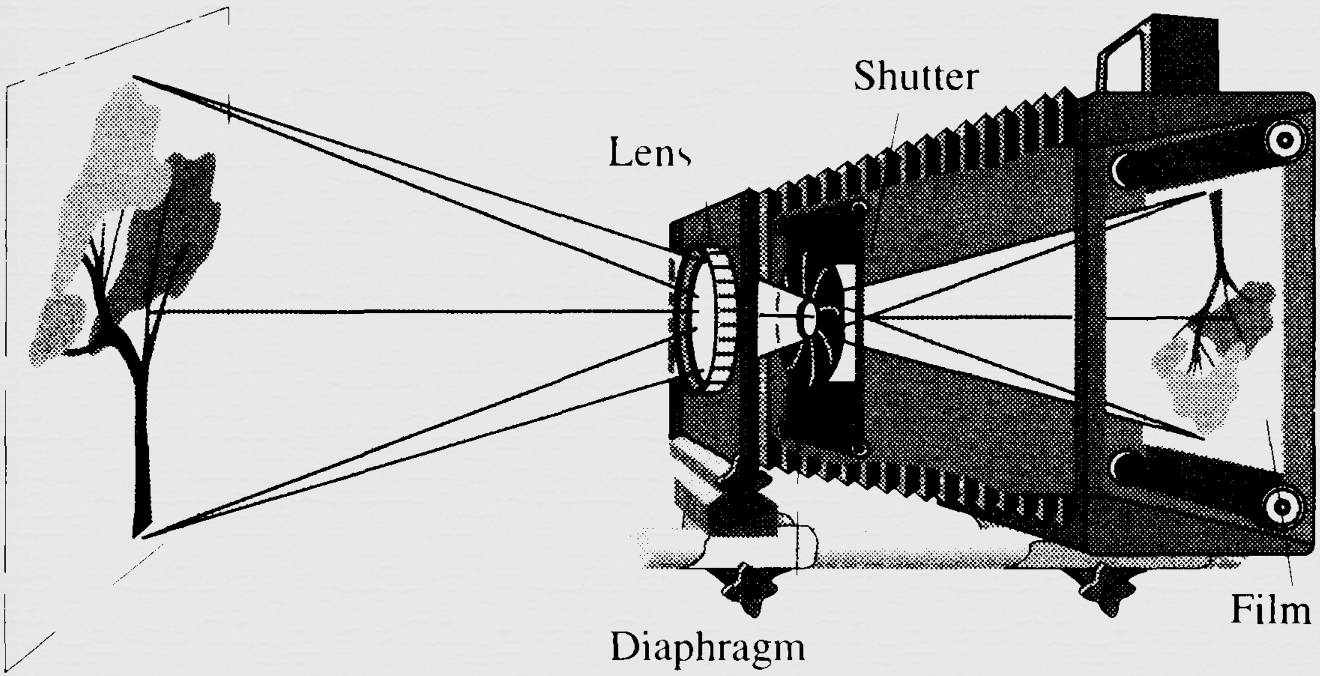
Pupils & Stops for a 3-Lens System



Vignetting



Relative Aperature & f/#



$$f/\# = \frac{f}{D}$$

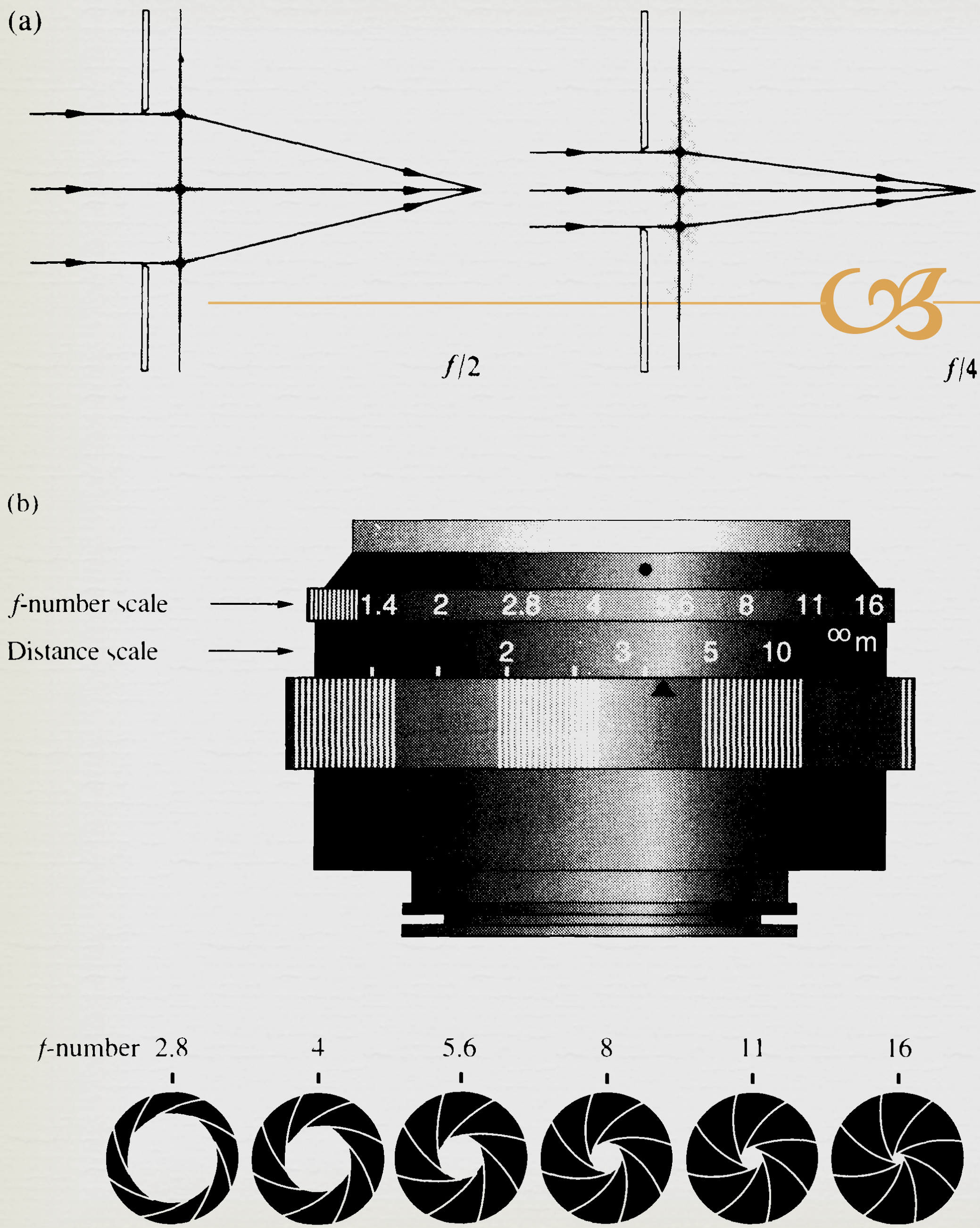
Speed of lens

Power $P \propto D^2$

Area of image $A \propto y_i^2 = (M_T y_o)^2 = (\frac{f}{x_o} y_o)^2 = f^2 \left(\frac{y_0}{x_0}\right)^2$

$$I = \frac{P}{A} \propto \left(\frac{D}{f}\right)^2 = \frac{1}{(f/\#)^2}$$

f-Number



$$I = \frac{P}{A} \propto \left(\frac{D}{f}\right)^2 = \frac{1}{(f\,/\,\#)^2}$$

Exposure time

$$t \propto \frac{1}{I} \propto (f\,/\,\#)^2$$