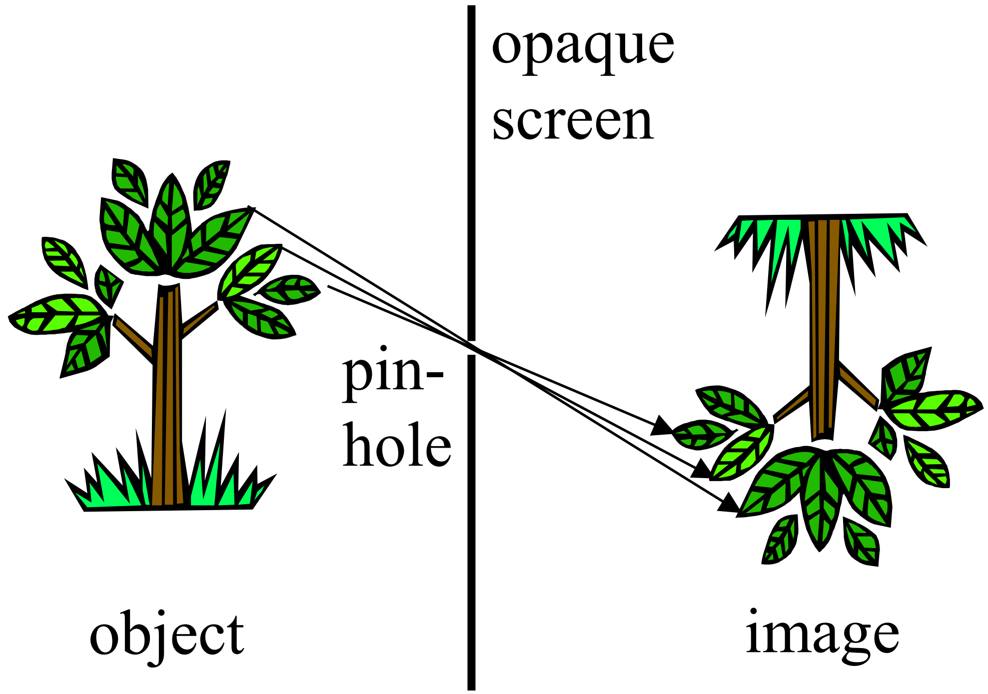
Mirrors & prisms

- Last time: optical elements,
  - Pinhole camera
  - Lenses
    - Basic properties of spherical surfaces
    - Ray tracing
    - Image formation
    - Magnification
- Today: more optical elements,
  - Prisms
  - Mirrors

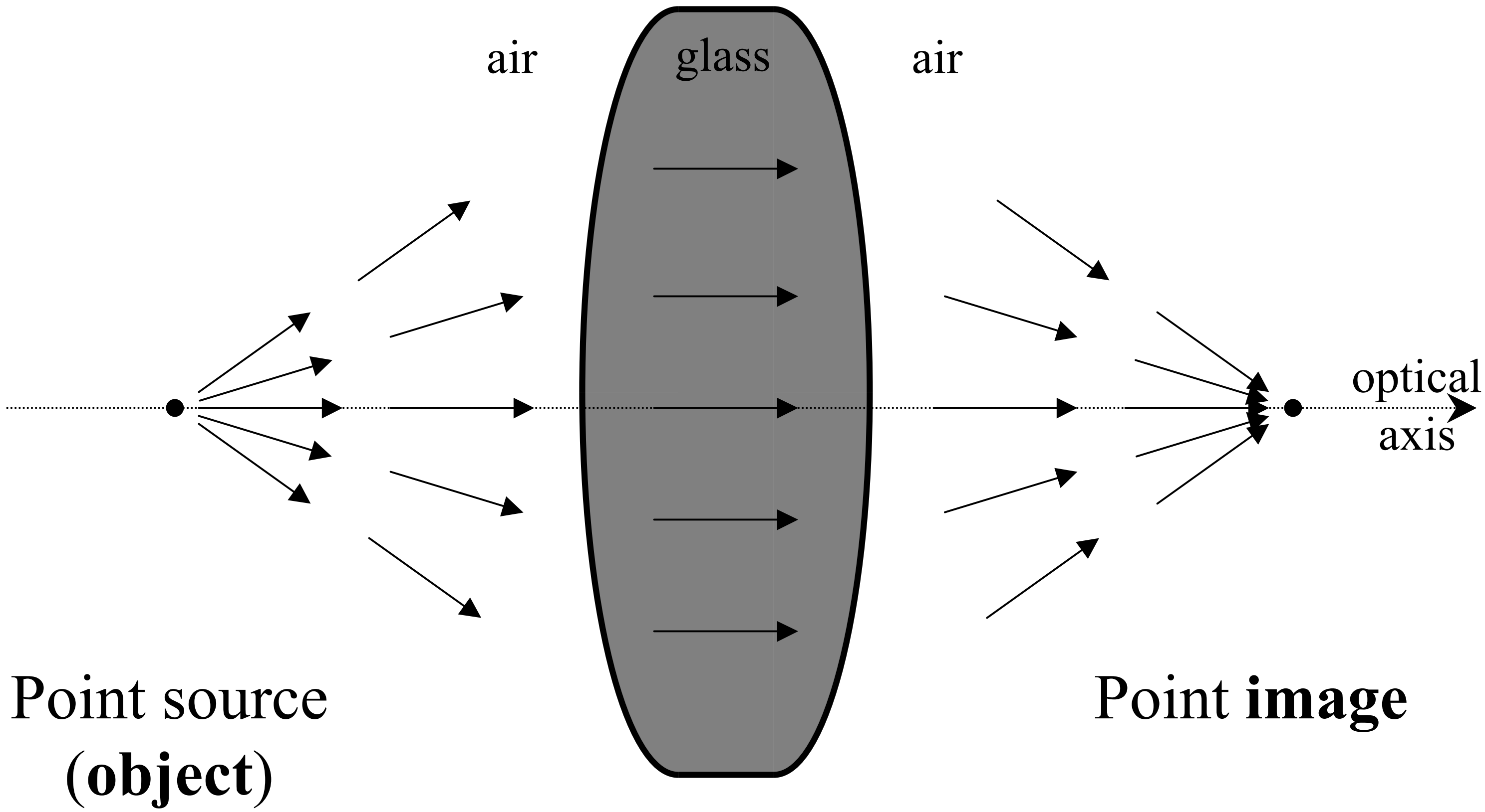
The pinhole camera



• The pinhole camera allows only one ray per object point to reach the image space ⇒ performs an imaging function.

• Unfortunately, most of the light is wasted in this instrument.

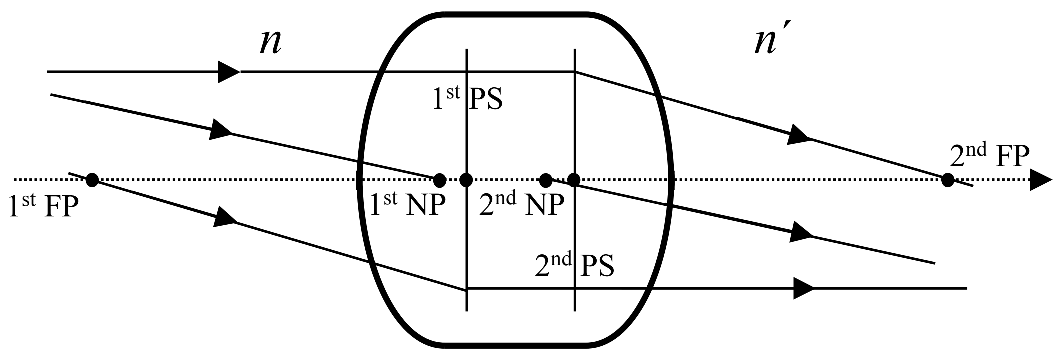
Lens: main instrument for image formation



The curved surface makes the rays bend proportionally to their distance from the "optical axis", according to Snell's law. Therefore, the divergent wavefront becomes convergent at the right-hand (output) side.

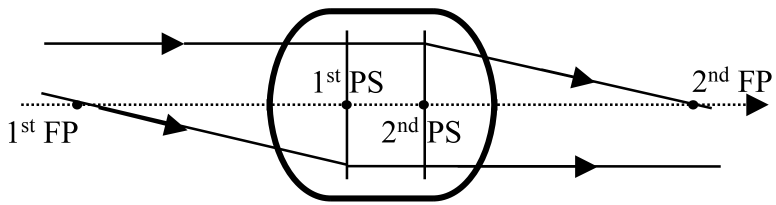
Cardinal Planes and Points

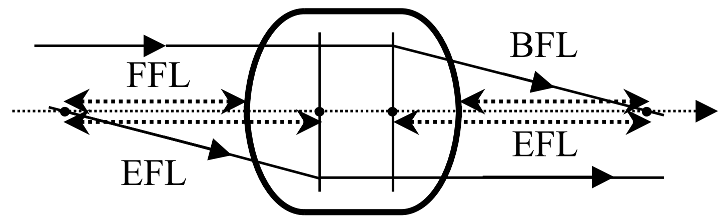
- Rays generated from axial point at infinity (*i.e.*, forming a ray bundle parallel to the optical axis) and entering an optical system intersect the optical axis at the Focal Points.
- The intersection of the extended entering parallel rays and the extended exiting convergent rays forms the Principal Surface (Plane in the paraxial approximation.)
- The extension of a ray which enters and exits the optical system with the same angle of propagation intersects the optical axis at the Nodal Points.



Recap of lens-like instruments

- Cardinal Points and Focal Lengths





$$\begin{pmatrix} n'\alpha' \\ x' \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \begin{pmatrix} n\alpha \\ x \end{pmatrix}$$

Matrix formulation

- Imaging conditions

$$M_{12} \neq 0$$

$$P = -M_{12} \neq 0$$

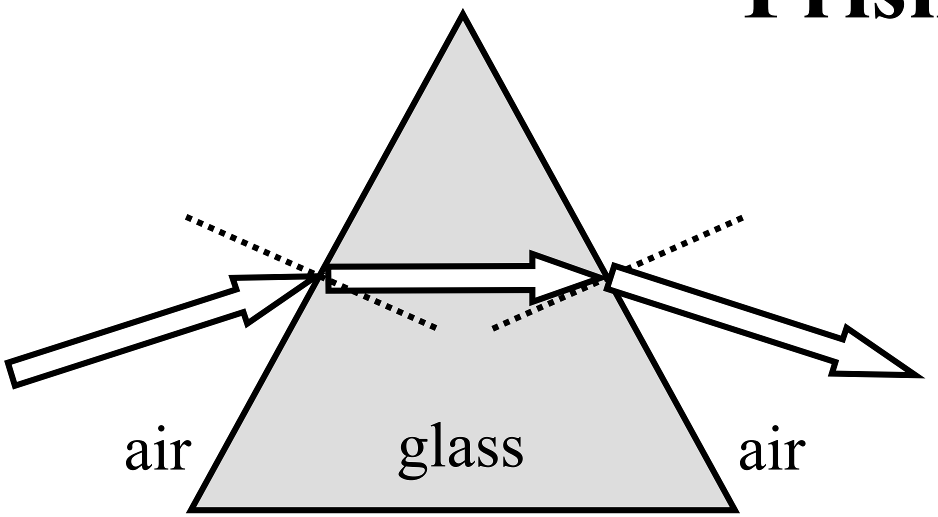
$$M_{21} = 0$$

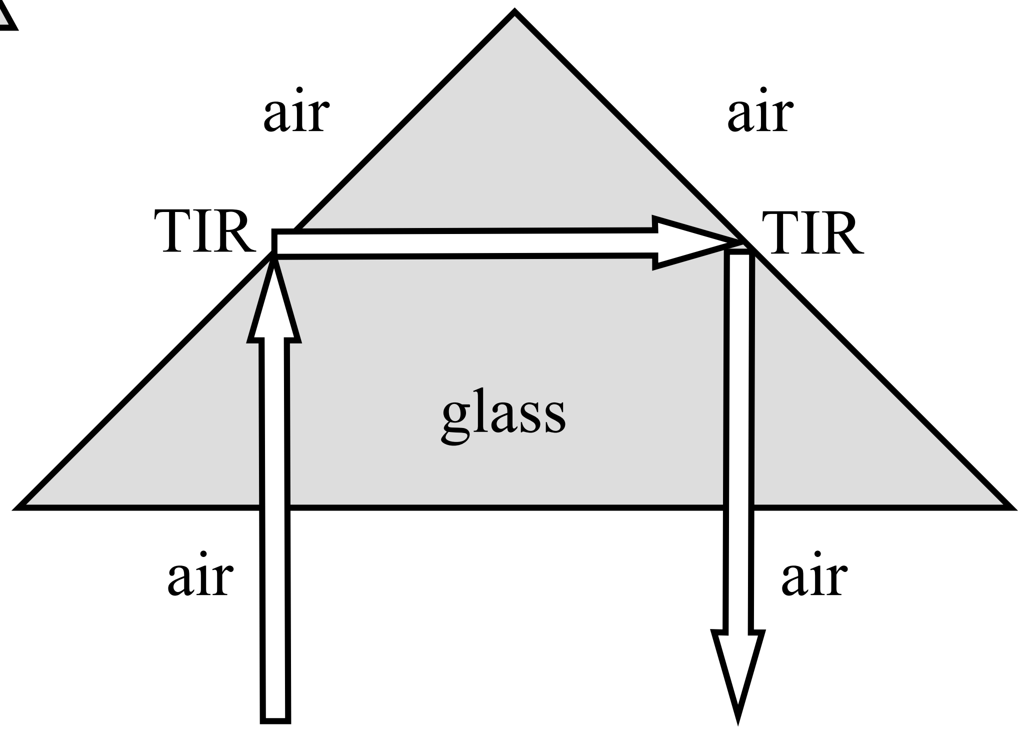
Magnification

lateral $m_x = M_{22}$

angular $m_a = \frac{n}{n'} M_{11}$

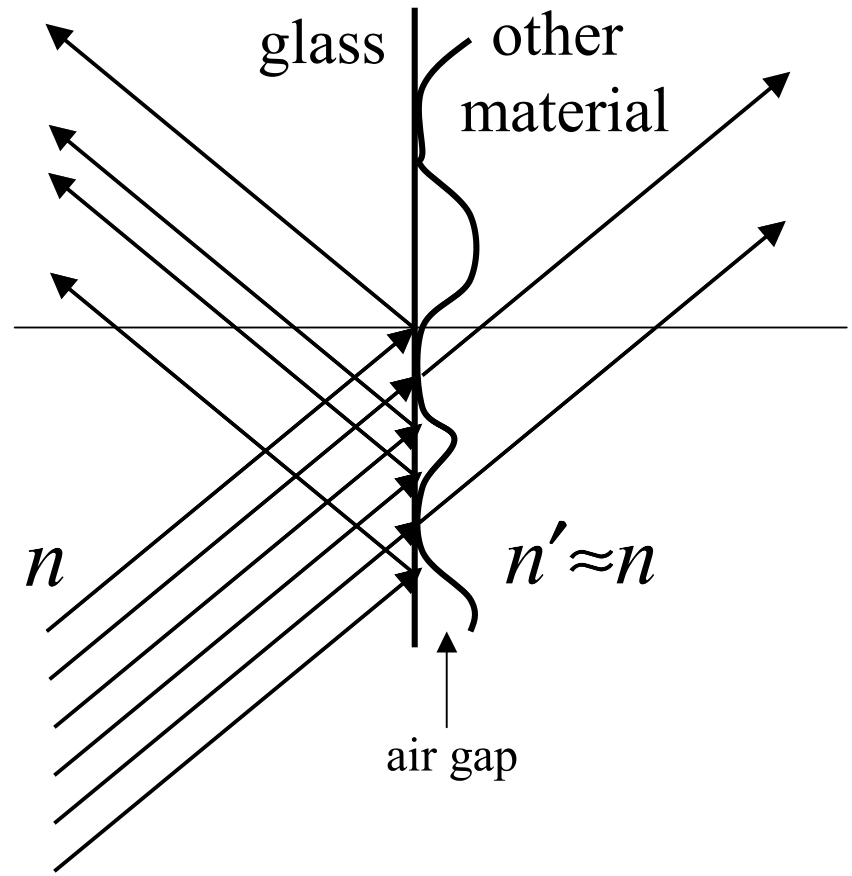
Prisms





Frustrated Total Internal Reflection (FTIR)

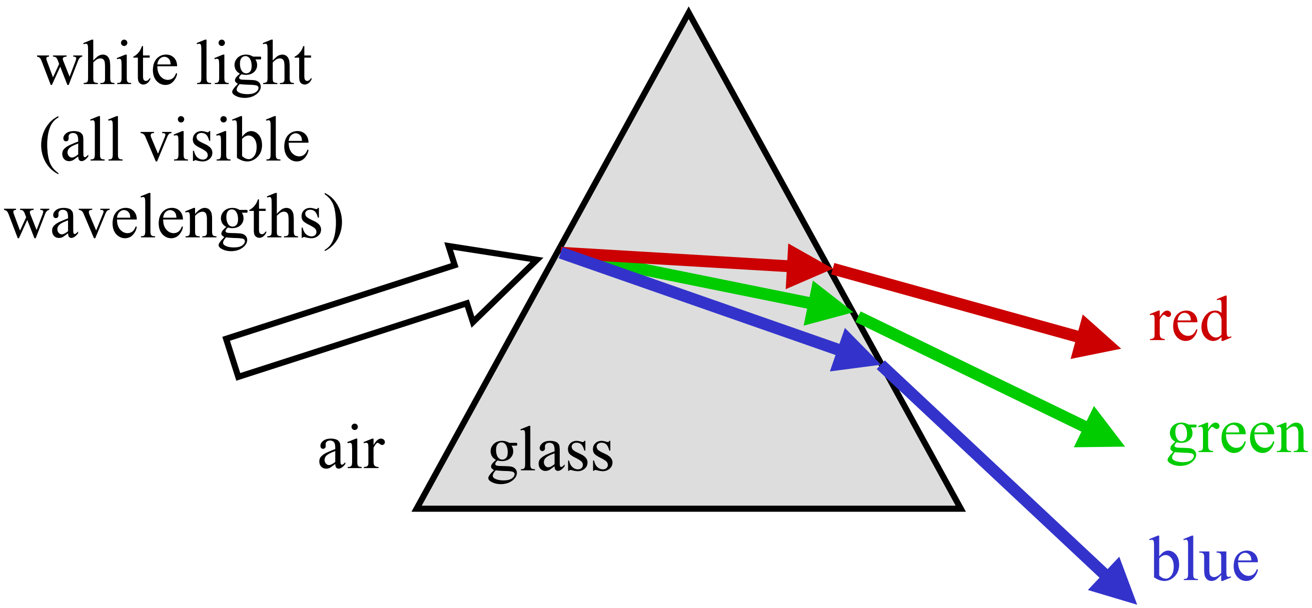
Reflected rays are missing where index-matched surfaces touch ⇒ shadow is formed



Angle of incidence exceeds critical angle

Dispersion

Refractive index *n* is function of the wavelength



Newton's prism

Dispersion measures

Reference color lines
C (H- λ=656.3nm, red), D (Na- λ=589.2nm, yellow),
F (H- λ=486.1nm, blue)

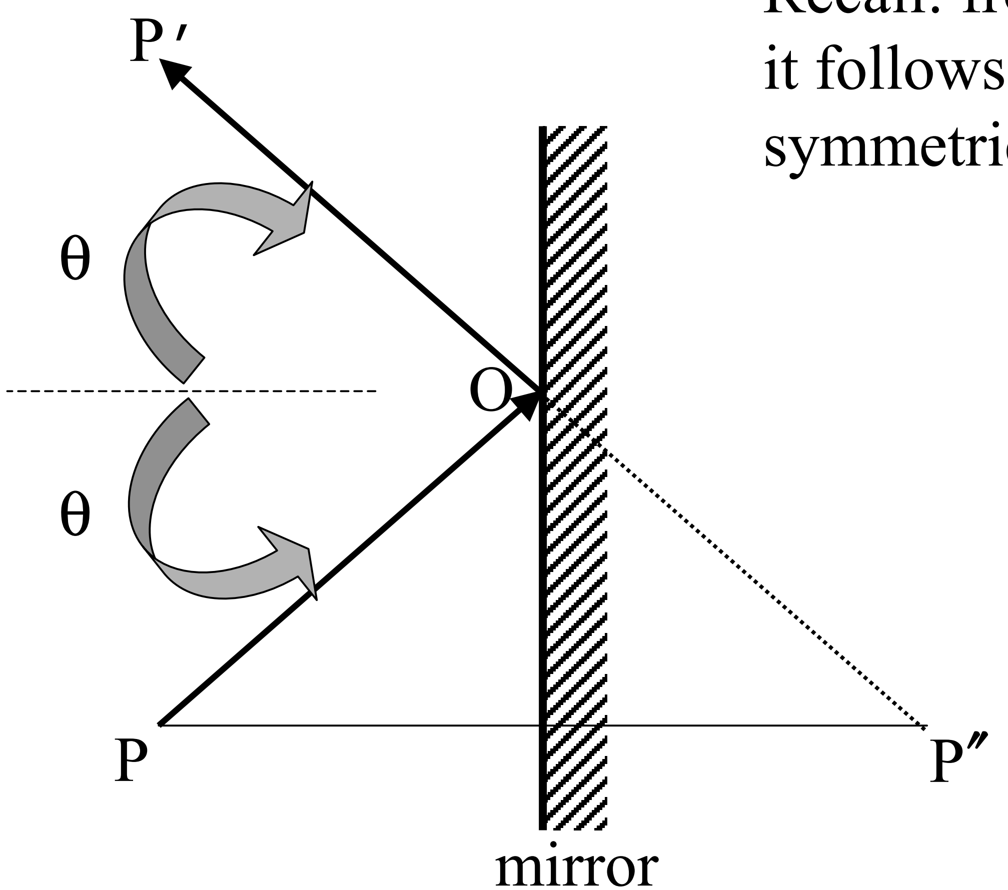
Crown glass has

$n_{\mathrm{F}} = 1.52933 \qquad n_{\mathrm{D}} = 1.52300 \qquad n_{\mathrm{C}} = 1.52042$

Dispersive power $V = \dfrac{n_{\mathrm{F}} - n_{\mathrm{C}}}{n_{\mathrm{D}} - 1}$

Dispersive index $\nu = \dfrac{1}{V} = \dfrac{n_{\mathrm{D}} - 1}{n_{\mathrm{F}} - n_{\mathrm{C}}}$

Mirrors: the law of reflection

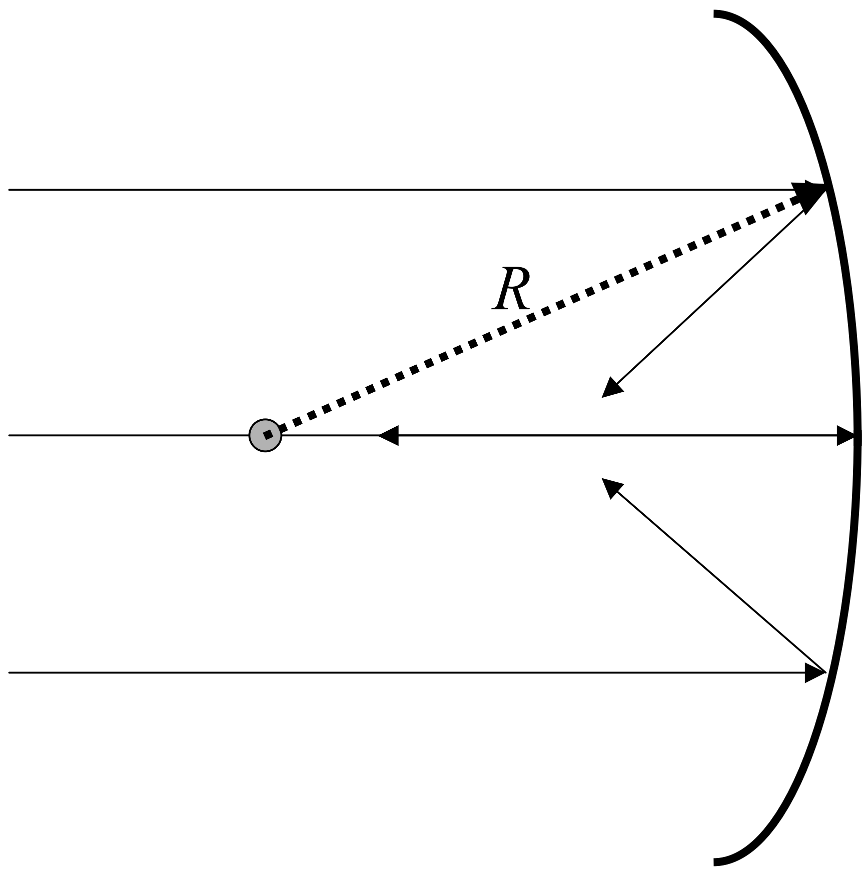


Recall: from Fermat's principle it follows that light follows the symmetric path POP'.

Sign conventions for reflection

- Light travels from left to right *before reflection and from right to left after reflection*
- A radius of curvature is positive if the surface is convex towards the left
- Longitudinal distances *before reflection* are positive if pointing to the right; *longitudinal distances after reflection are positive if pointing to the left*
- Longitudinal distances are positive if pointing up
- Ray angles are positive if the ray direction is obtained by rotating the +z axis counterclockwise through an acute angle

Example: spherical mirror



In the paraxial approximation,
It (approximately) focuses an
Incoming parallel ray bundle
(from infinity) to a point.

Reflective optics formulae

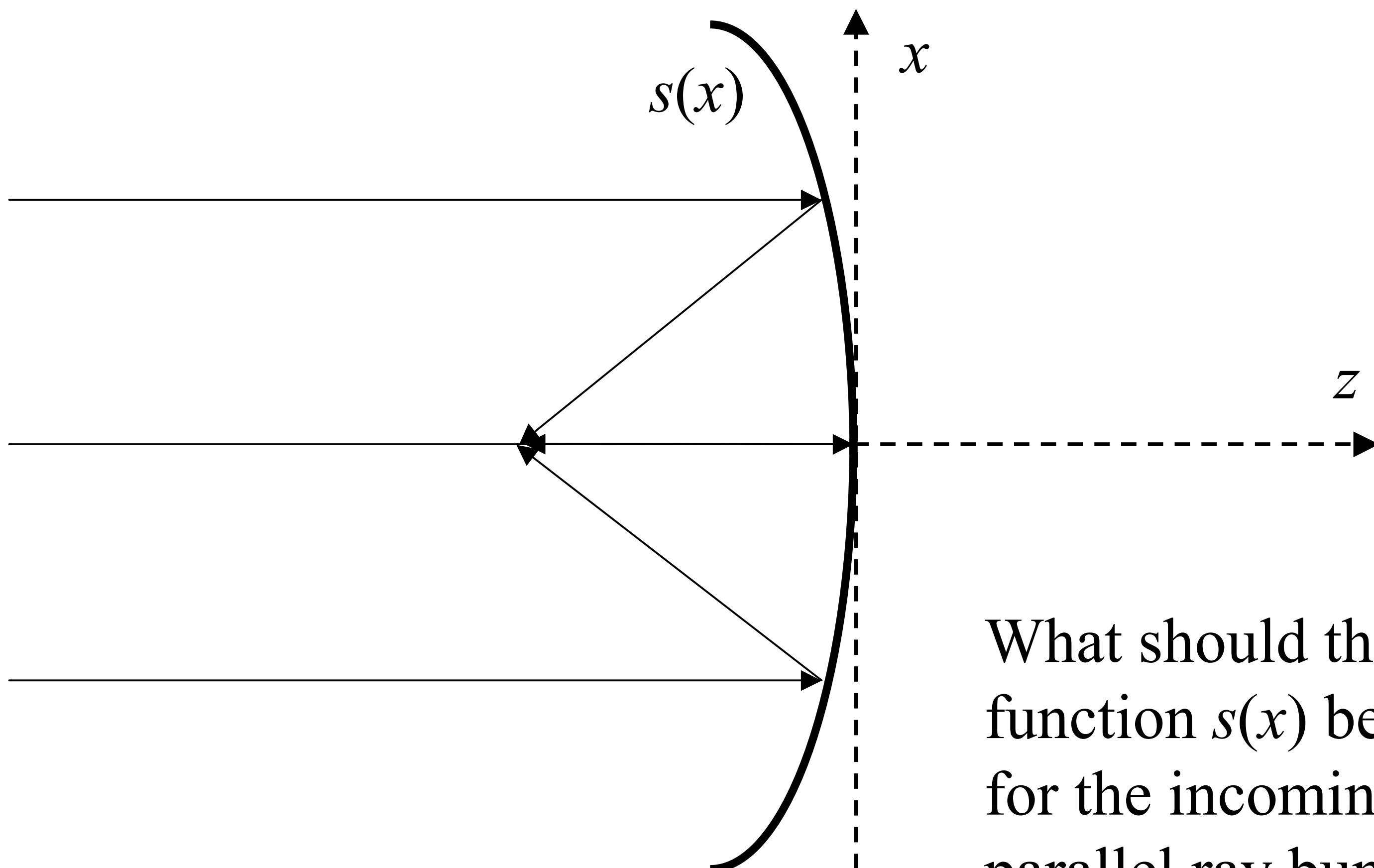
Imaging condition $$\frac{1}{D_{12}}+\frac{1}{D_{01}}=-\frac{2}{R}$$

Focal length $$f=-\frac{R}{2}$$

Magnification $$m_x=-\frac{D_{12}}{D_{01}} \qquad m_\alpha=-\frac{D_{01}}{D_{12}}$$

Parabloid mirror: <u>perfect</u> focusing

(e.g. satellite dish)



What should the shape function $s(x)$ be in order for the incoming parallel ray bundle to come to perfect focus?