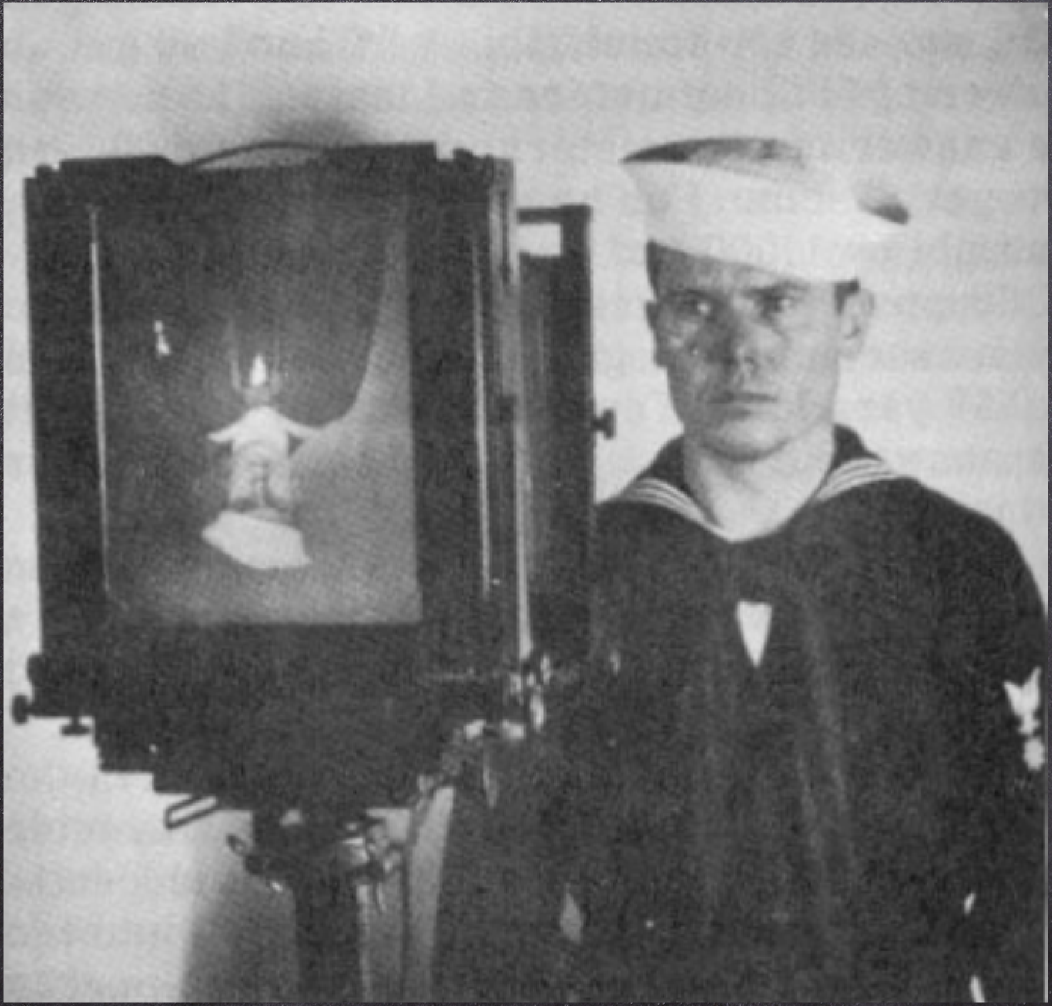
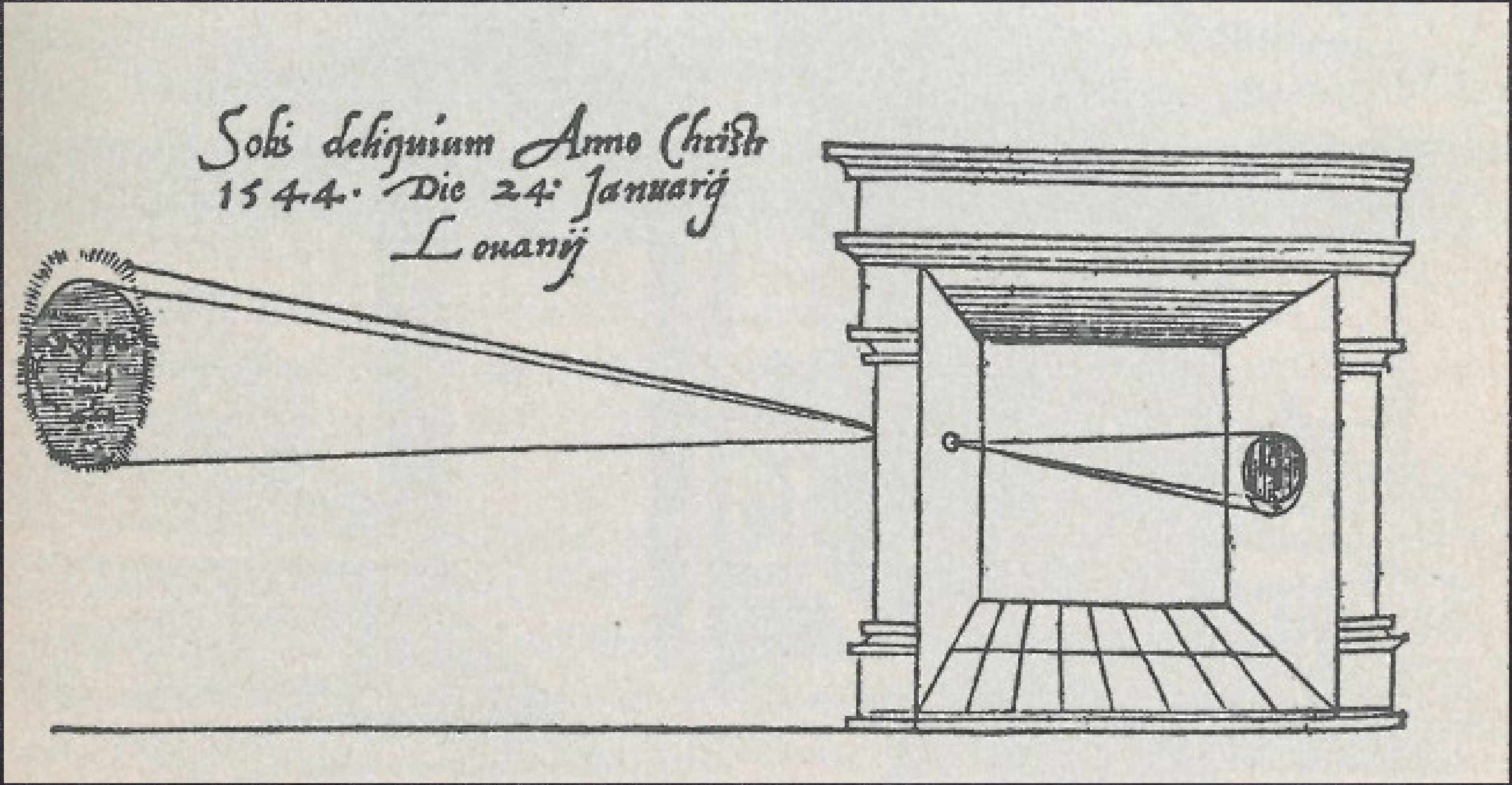
计算视觉与模式识别

照相机与摄像机



针孔相机



First published illustration of camera obscura in Gemma Frisius' book "De Radio Astronomica et Geometrica," 1545 (Photo: Wikimedia Commons, Public domain)https://mymodernmet.com/camera-obscura/

透视投影

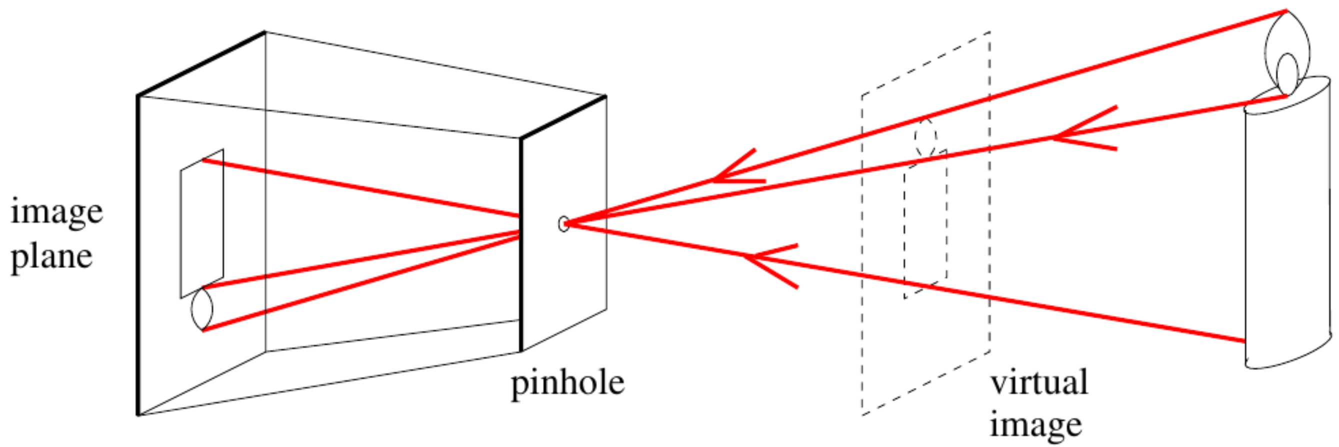
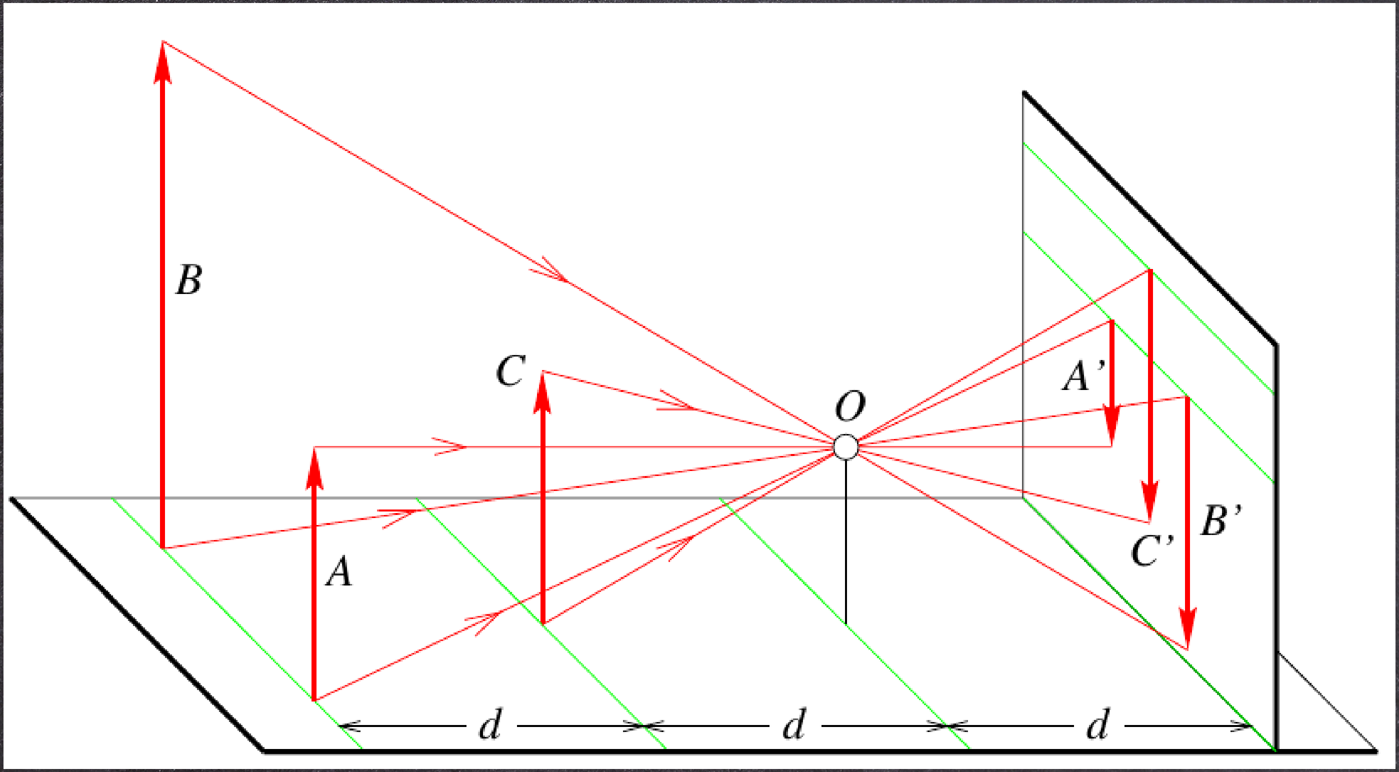


Figure 1.2. The pinhole imaging model.


B
C
A
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A'
B'
C'
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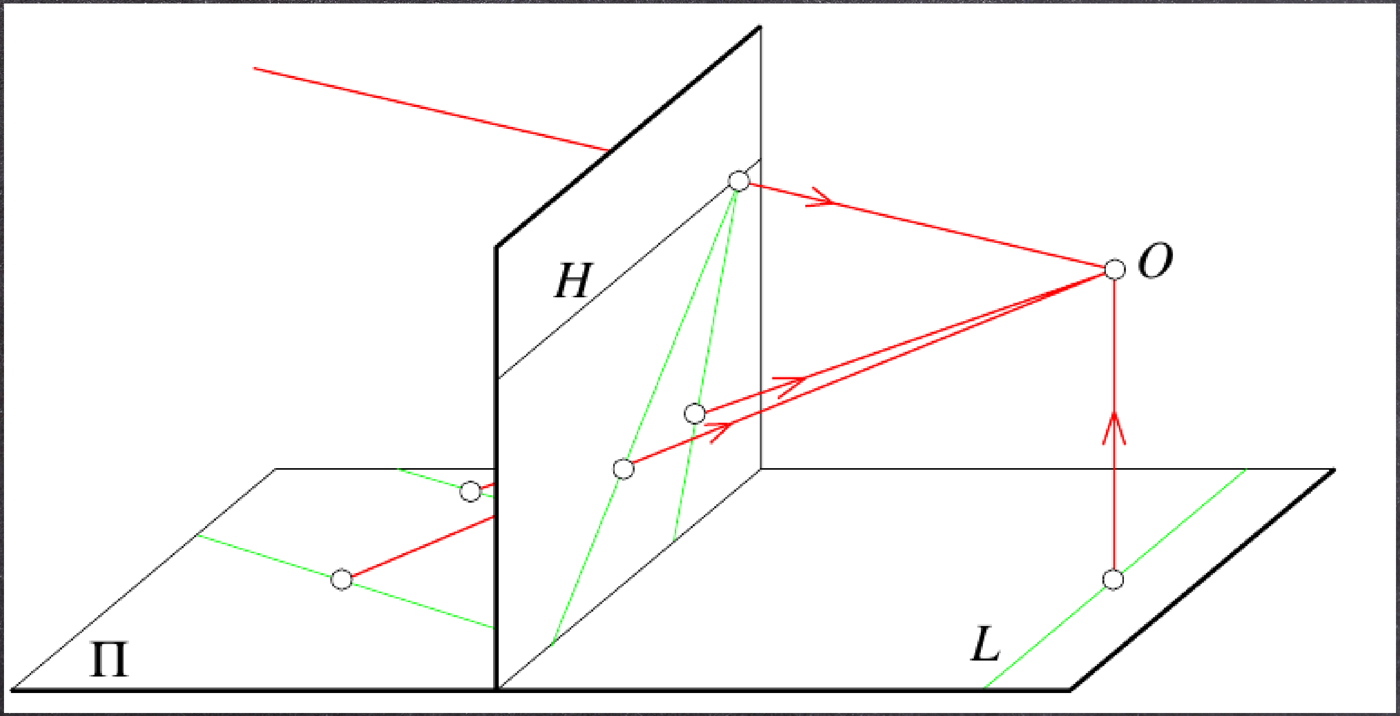
H
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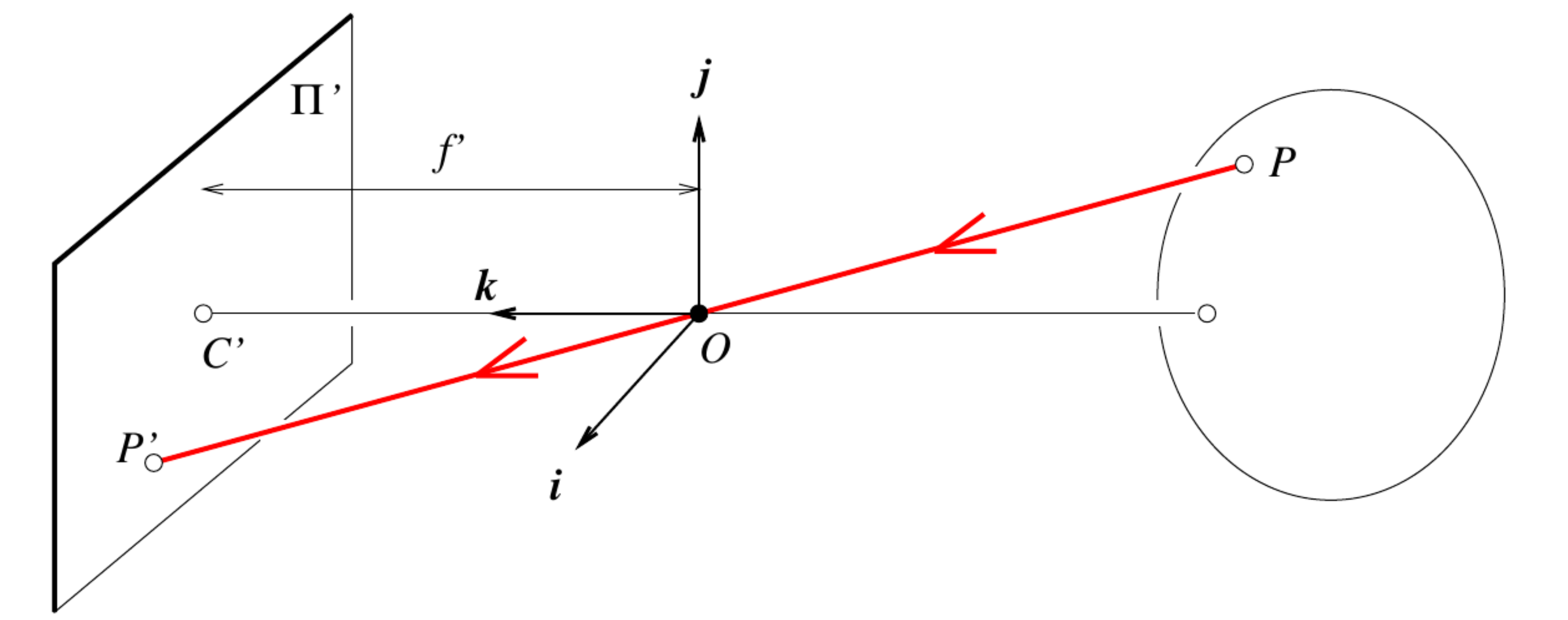


Figure 1.4. The perspective projection equations are derived in this section from the colinearity of the point P, its image P' and the pinhole O.

透视投影模型

$$\begin{pmatrix} x' \\ y' \\ f' \end{pmatrix} = \lambda \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

$$\lambda = \frac{x'}{x} = \frac{y'}{y} = \frac{f'}{z}$$

therefore

$$\begin{aligned} x' &= f'\frac{x'}{z} \\ y' &= f'\frac{y'}{z} \end{aligned}$$

弱透视投影

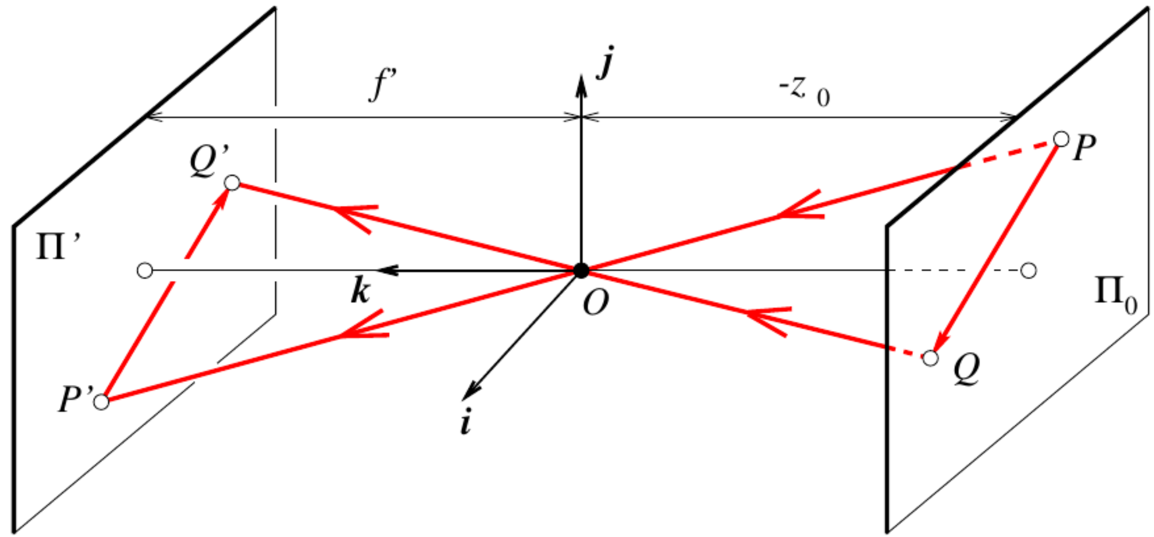


Figure 1.5. Weak-perspective projection: all line segments in the plane Π_0 are projected with the same magnification.

弱透视投影模型

$$
\begin{aligned}
x' &= -mx \\
y' &= -my
\end{aligned}
$$

where

$$
m = -\frac{f'}{z_0}
$$

正交投影

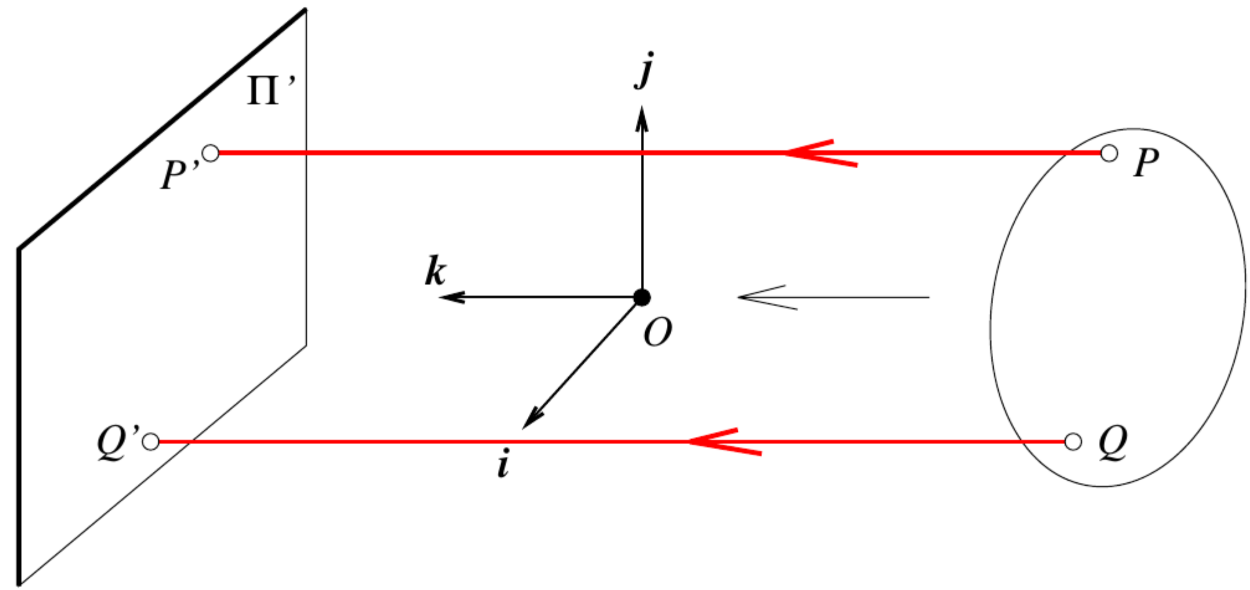


Figure 1.6. Orthographic projection. Unlike other geometric models of the image formation process, orthographic projection does not involve a reversal of image features. Accordingly, the magnification is taken to be negative, which is a bit unnatural but simplifies the projection equations.

正交投影模型

$$
\begin{aligned}
x' &= x \\
y' &= y
\end{aligned}
$$

球面投影

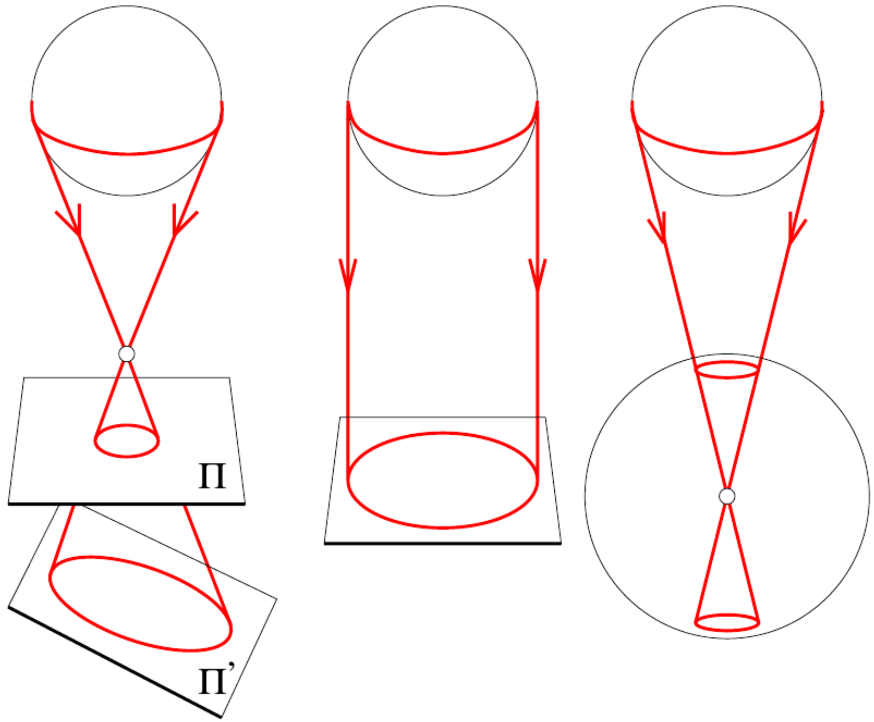


Figure 1.7. Different pictures of a sphere. Left: planar perspective projection. The shape of the sphere's silhouette depends on the orientation of the image plane: for a plane such as Π, which is orthogonal to the the line passing through the sphere center and the pinhole, the silhouette is a circle. For oblique planes such as Π', it is an ellipse (or possibly another conic section) instead. Middle: orthographic projection. Right: spherical perspective projection. The silhouette is always a circle under these two models.

带镜头的相机

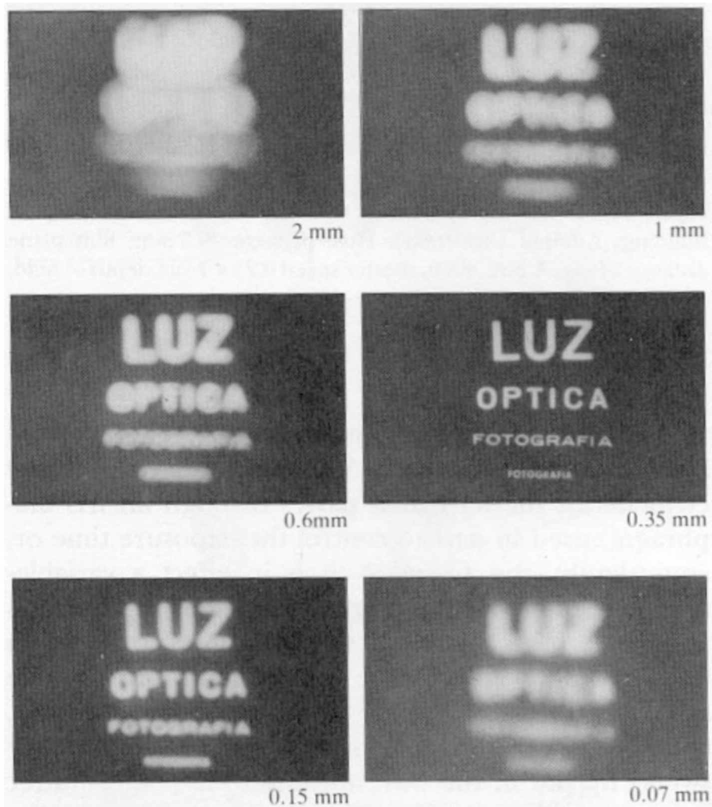


Figure 1.8. Images of some text obtained with shrinking pinholes: large pinholes give bright but fuzzy images but pinholes that are too small also give blurry images because of diffraction effects. Reprinted from [Hecht, 1987], Figure 5.108.

折射与反射

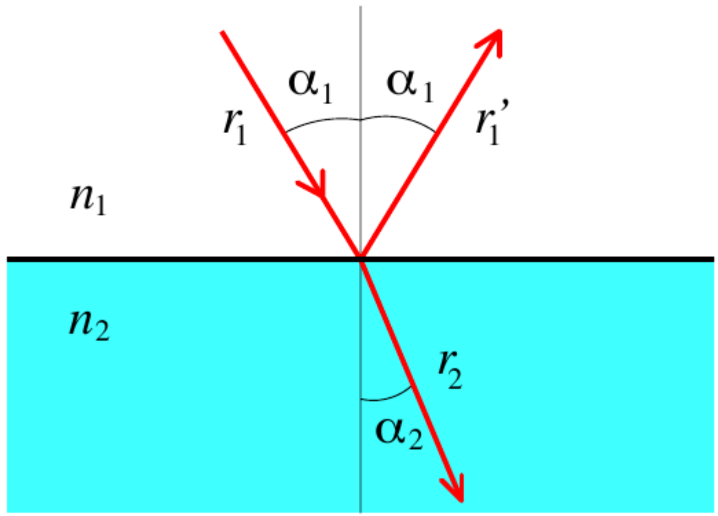


Figure 1.9. Reflection and refraction at the interface between two homogeneous media with indices of refraction n_1 and n_2.

$$n_1 \sin\alpha_1 = n_2 \sin\alpha_2$$

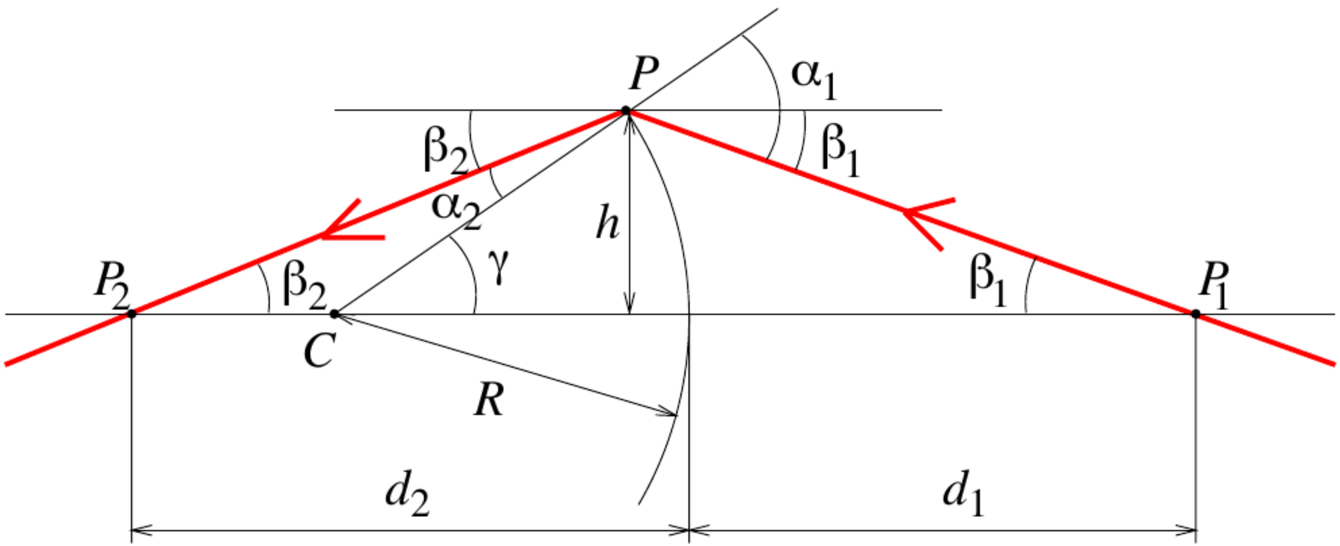


Figure 1.10. Paraxial refraction: a light ray passing through the point P is refracted at the point P_1 where it intersects a circular interface. The refracted ray intersects the optical axis in P_2. The center of the interface is at the point C of the optical axis, and its radius is R. The angles α_1, β_1, α_2 and β_2 are all assumed to be small.

$$
\begin{aligned}
\alpha_1 &= \gamma + \beta_1 \\
&\approx h\left(\frac{1}{R} + \frac{1}{d_1}\right) \\
a_2 &= \gamma - \beta_2 \\
&\approx h\left(\frac{1}{R} - \frac{1}{d_2}\right) \\
n_1\alpha_1 &\approx n_2\alpha_2 \\
\frac{n_1}{d_1} + \frac{n_2}{d_2} &= \frac{n_2 - n_1}{R}
\end{aligned}
$$

薄透镜

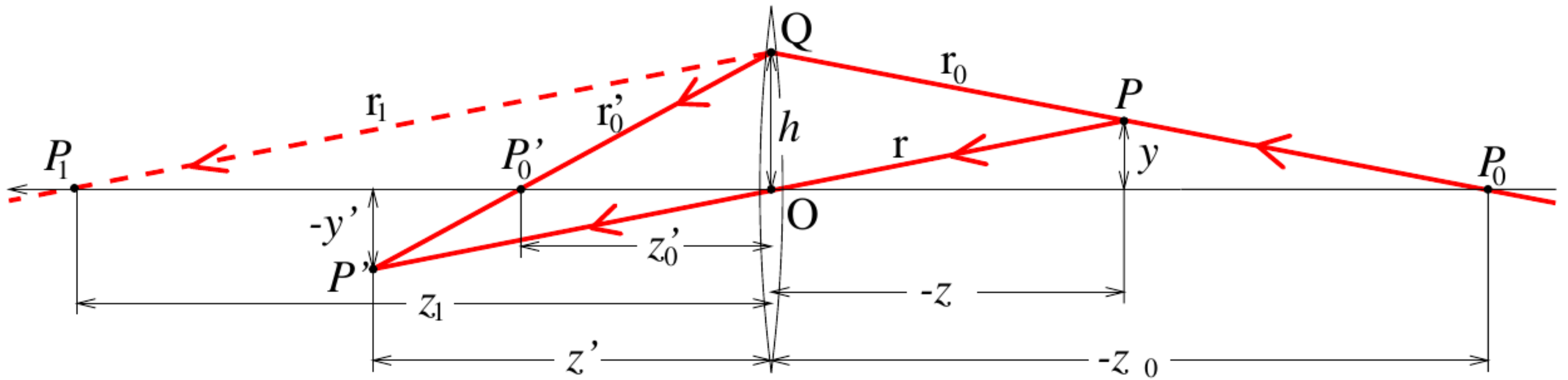


Figure 1.11. Image formation in the case of a thin lens. The ray r_1 is dashed to indicate that it will never actually reach the point P_1 since it will be refracted by the left boundary of the lens before that. Note that the z axis is oriented from right to left to ensure consistency with the previous figures, thus P and P_0 have negative depths z and z_0.

$$
\begin{aligned}
\frac{1}{R}+\frac{1}{-z_0} &= n\left(\frac{1}{R}-\frac{1}{z_1}\right)\\
n\left(\frac{1}{R}+\frac{1}{z_1}\right) &= \frac{1}{R}+\frac{1}{z_0'}\\
\frac{1}{z_0'}+\frac{1}{-z_0} &= \frac{2n-2}{R}\\
\frac{1}{z_0'}-\frac{1}{z_0} &= \frac{1}{f}
\end{aligned}
\qquad\qquad f=\frac{R}{2n-2}
$$

凸透镜成像

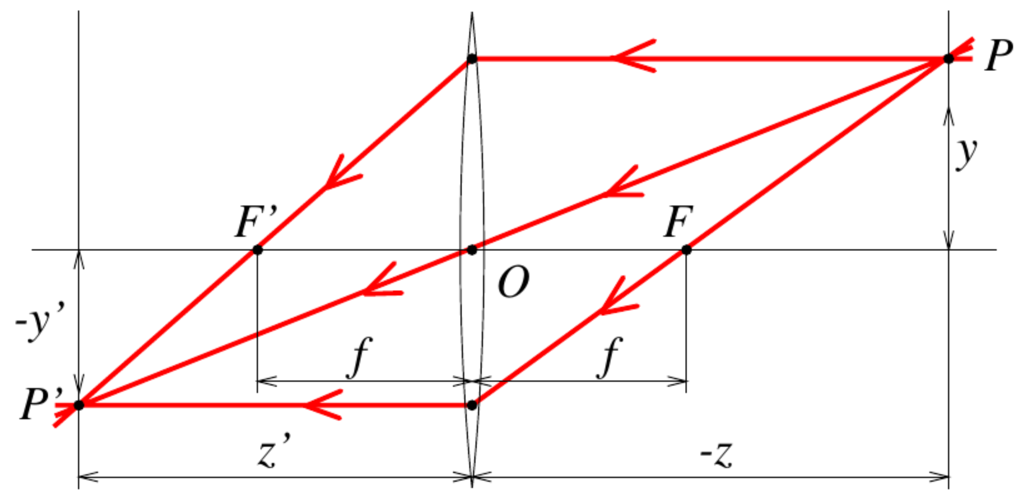


Figure 1.12. The focal points of a thin lens.

$$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$

视场

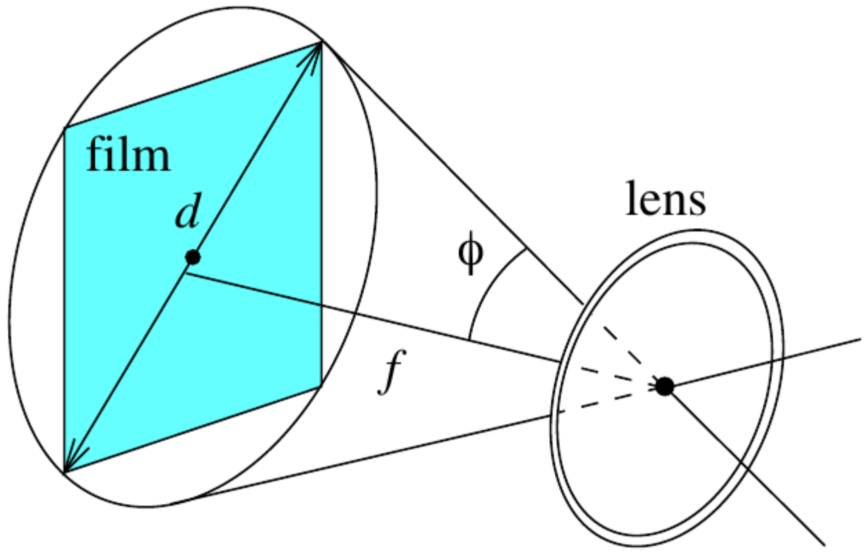


Figure 1.13. The field of view of a camera. It can be defined as 2ϕ, where $\phi \stackrel{\text{def}}{=} \arctan \frac{d}{2f}$, d is the diameter of the sensor (film or CCD chip) and f is the focal length of the camera.

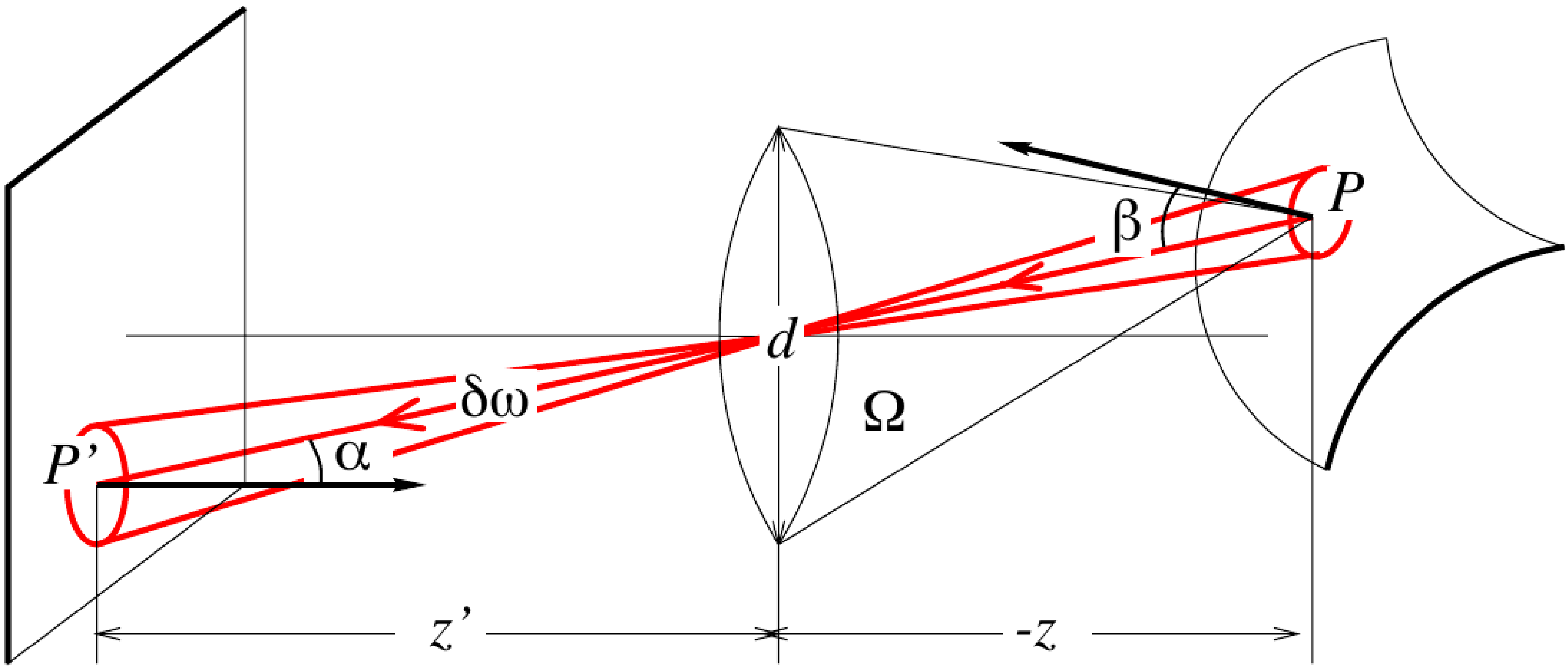


Figure 1.14. Object radiance and image irradiance.

$$
\begin{aligned}
\Omega &= \frac{\pi d^2}{4}\cdot \mathrm{co}\alpha\cdot\frac{1}{|\overrightarrow{\mathrm{OP}}|^2} \\
&= \frac{\pi d^2}{4}\cdot\frac{\cos^3\alpha}{z^2} \\
\delta P &= L\Omega\delta A\cos\beta \\
&= \frac{\pi d^2}{4}\cdot\frac{\cos^3\alpha}{z^2}L\cos\beta\delta A \\
E &= \frac{\delta P}{\delta A'} \\
&= \frac{\pi d^2}{4}\cdot\frac{\cos^3\alpha}{z^2}L\cos\beta\frac{\delta A}{\delta A'}
\end{aligned}
$$

$$
\begin{aligned}
\frac{\delta A \cos\beta}{|\overrightarrow{\mathrm{OP}}|^2} &= \frac{\delta A' \cos\alpha}{|\overrightarrow{\mathrm{OP'}}|^2} \\
\delta A \cos\beta \cdot \frac{\cos^2\alpha}{z} &= \delta A' \cos^3\alpha \cdot \frac{\cos^2\alpha}{z'} \\
\frac{\delta A}{\delta A'} &= \frac{\cos\alpha}{\cos\beta}\left(\frac{z}{z'}\right)^2 \\
E &= \frac{\pi d^2}{4} \cdot \frac{\cos^3\alpha}{z^2} L \cos\beta \frac{\delta A}{\delta A'} \\
&= \frac{\pi}{4}\left(\frac{d}{z'}\right)^2 \cos^4\alpha L
\end{aligned}
$$

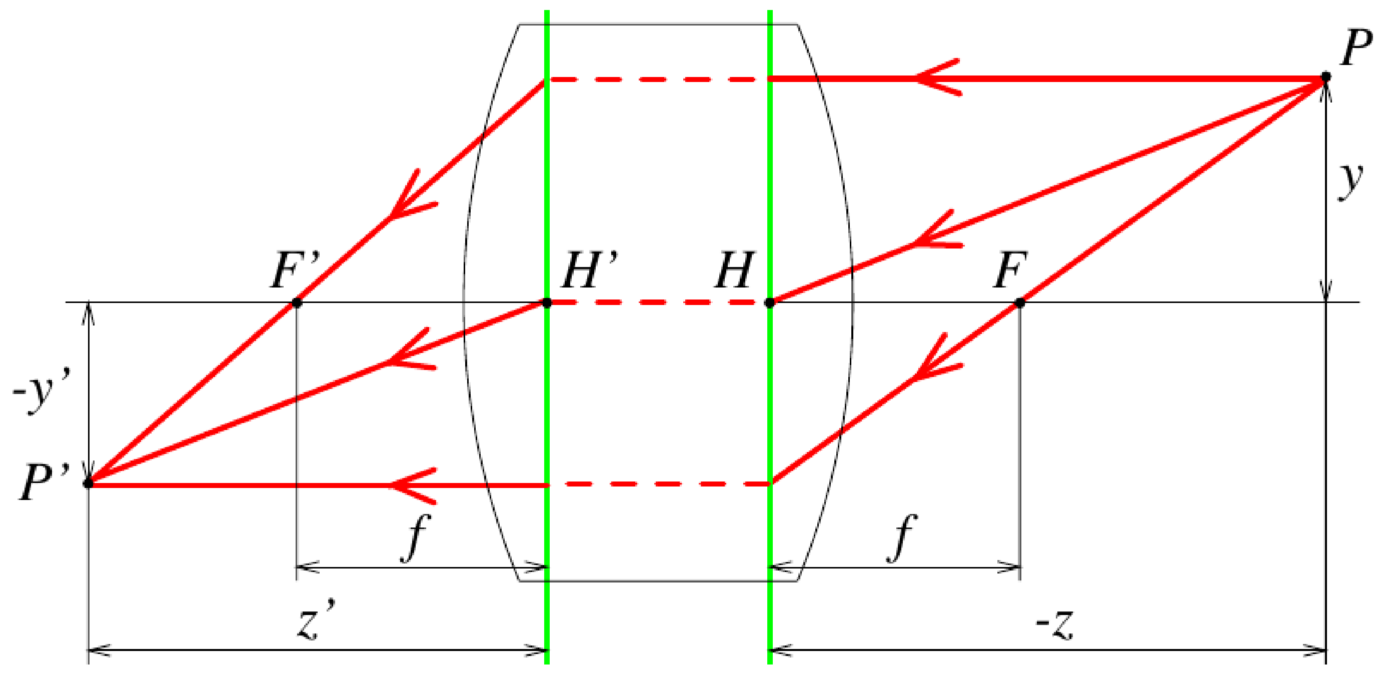
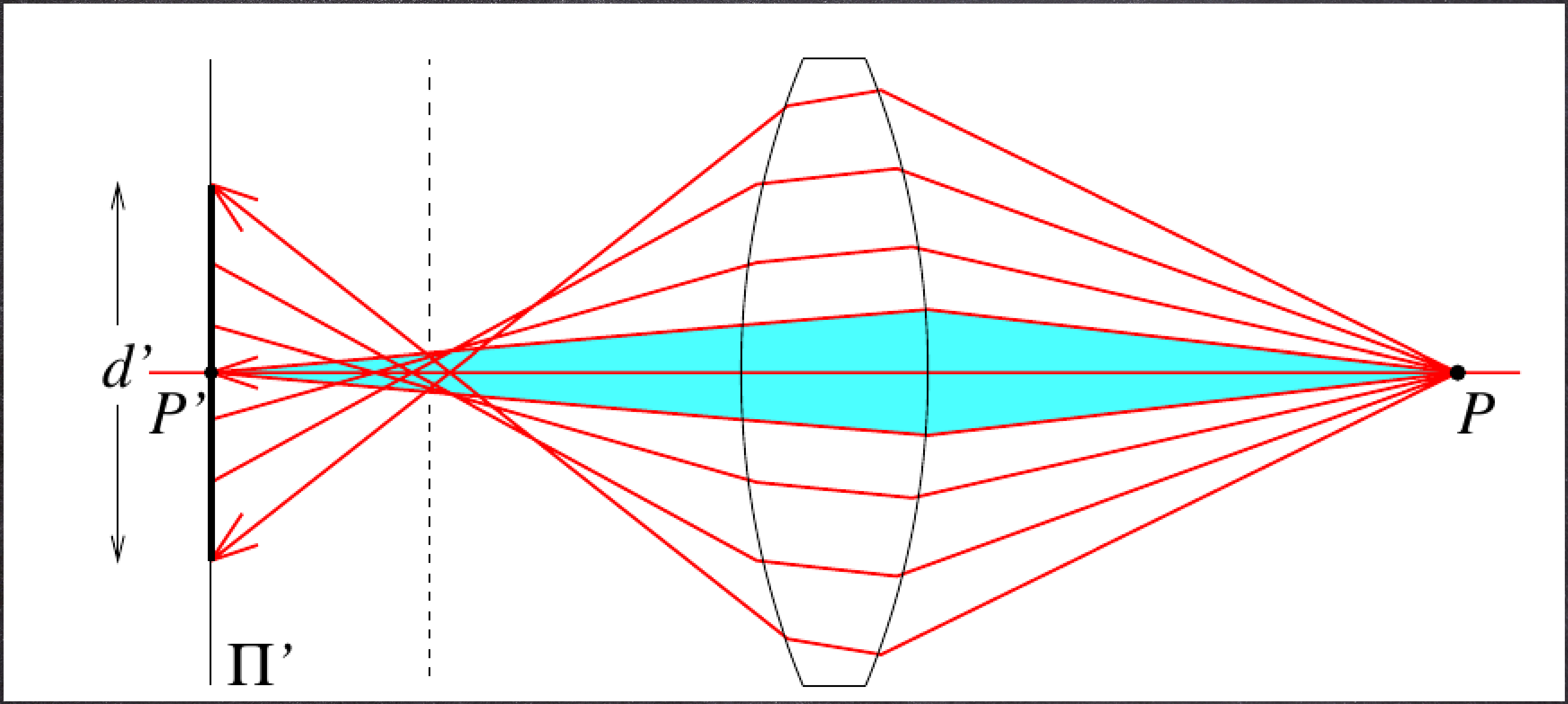
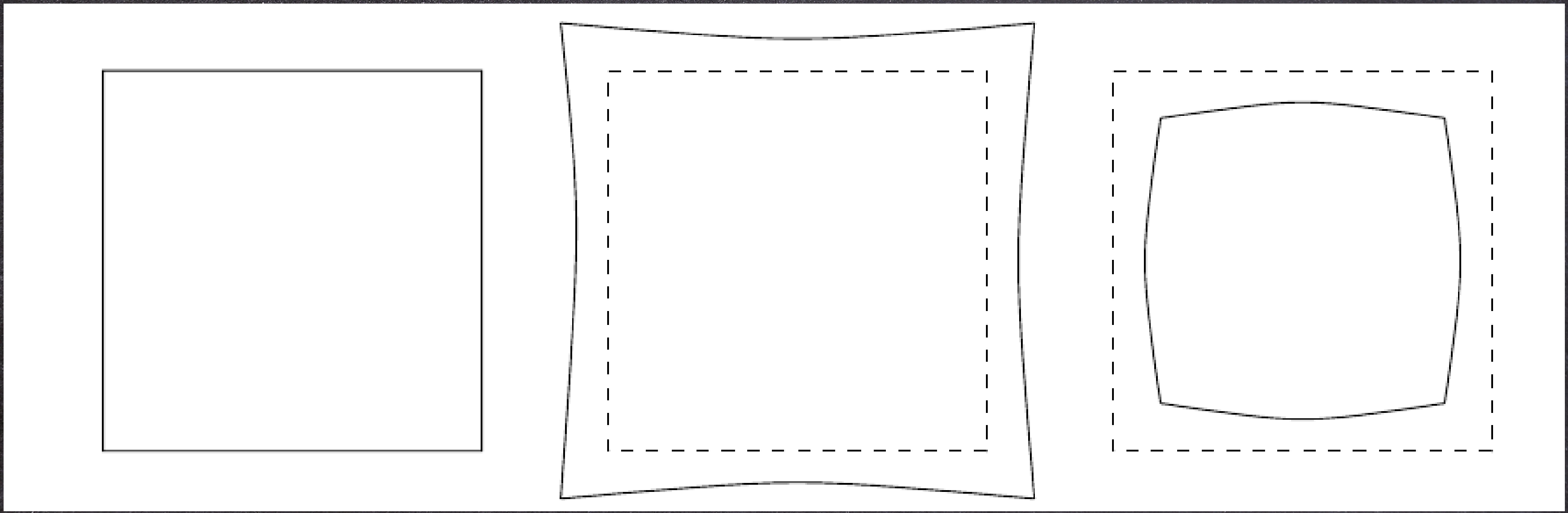


Figure 1.15. A simple thick lens with two spherical surfaces.

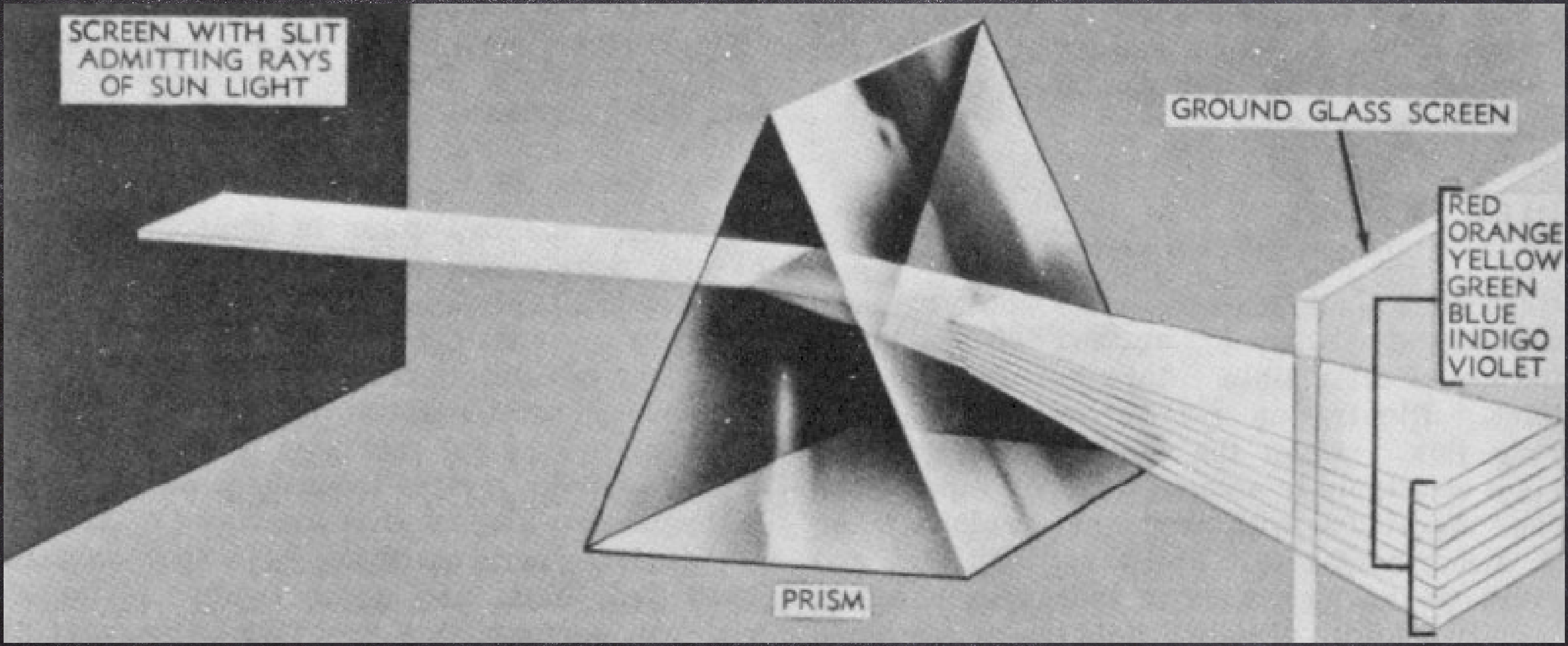
球面像差



畸变



色像差


SCREEN WITH SLIT ADMITTING RAYS OF SUN LIGHT
GROUND GLASS SCREEN
RED
ORANGE
YELLOW
GREEN
BLUE
INDIGO
VIOLET
PRISM

透镜组

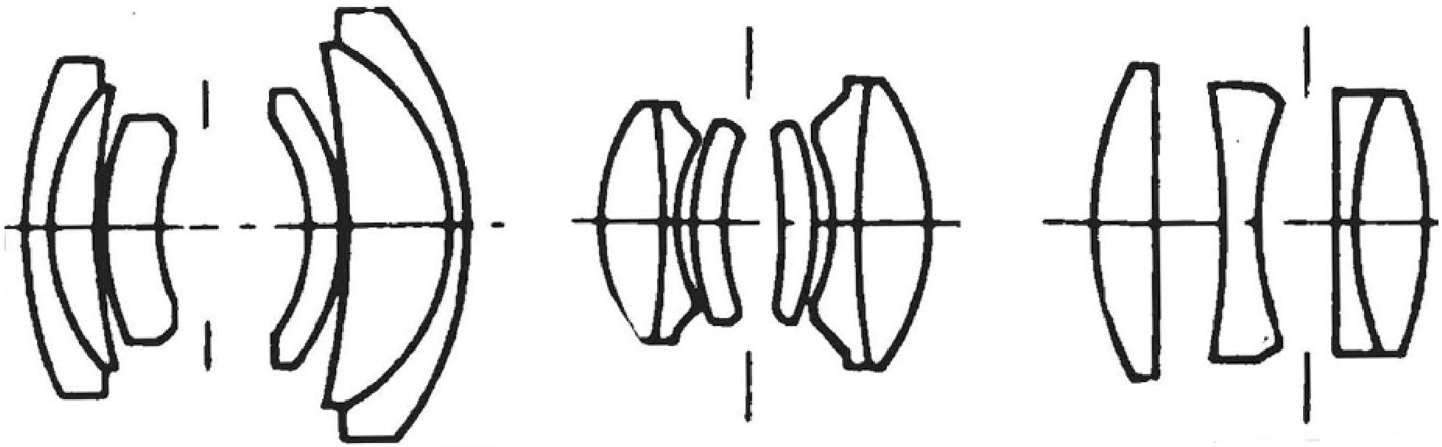


Figure 1.17. Photographics lenses. Reprinted from [Montel, 1972], p. 54.

渐晕

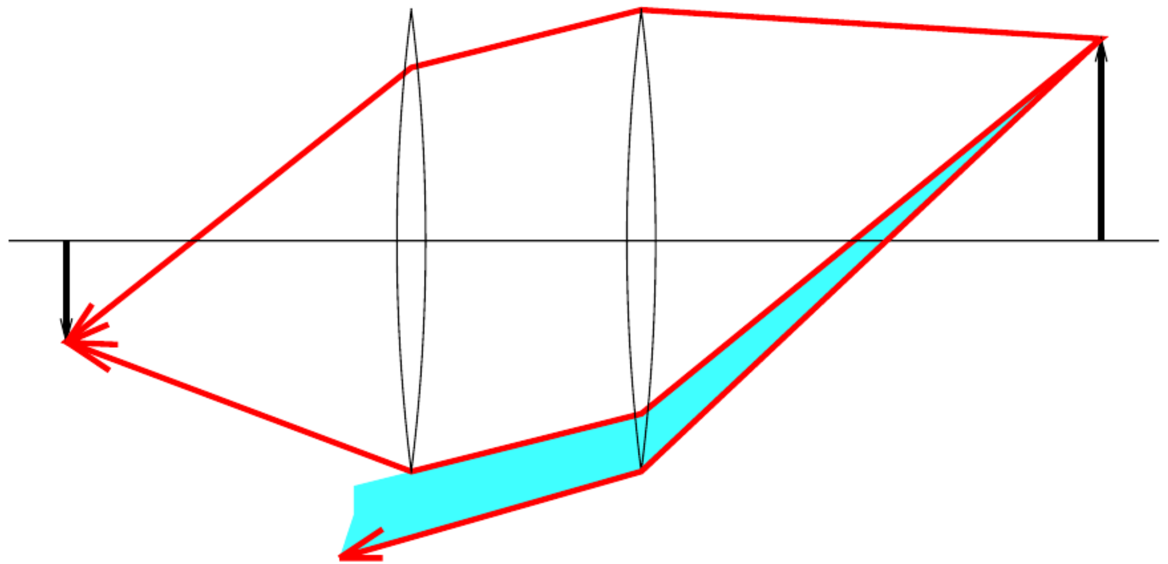
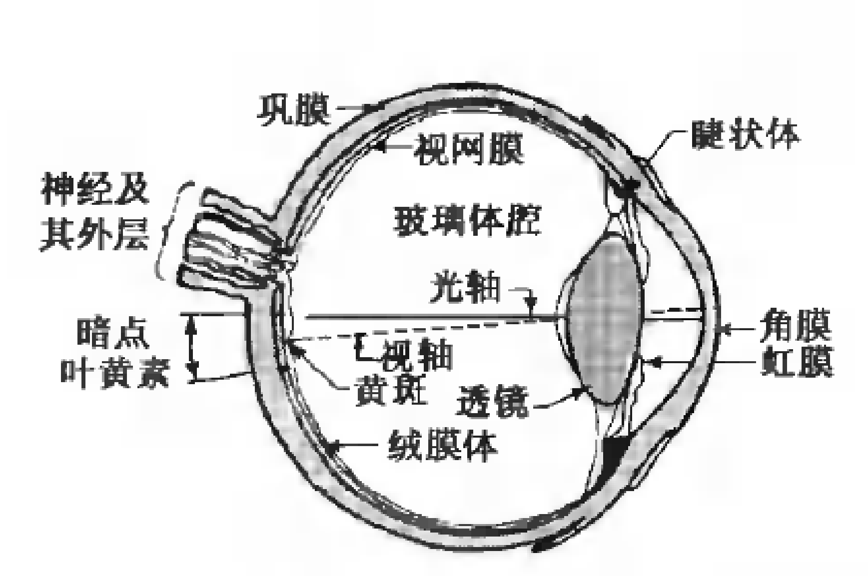
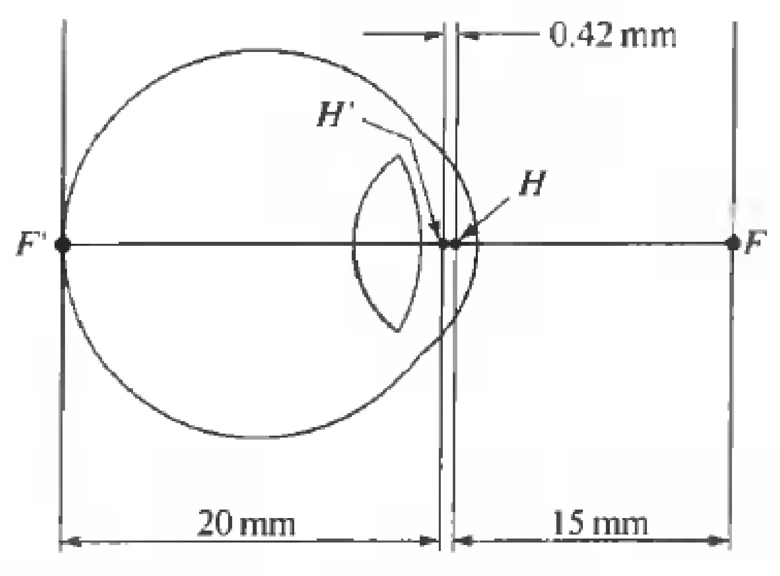


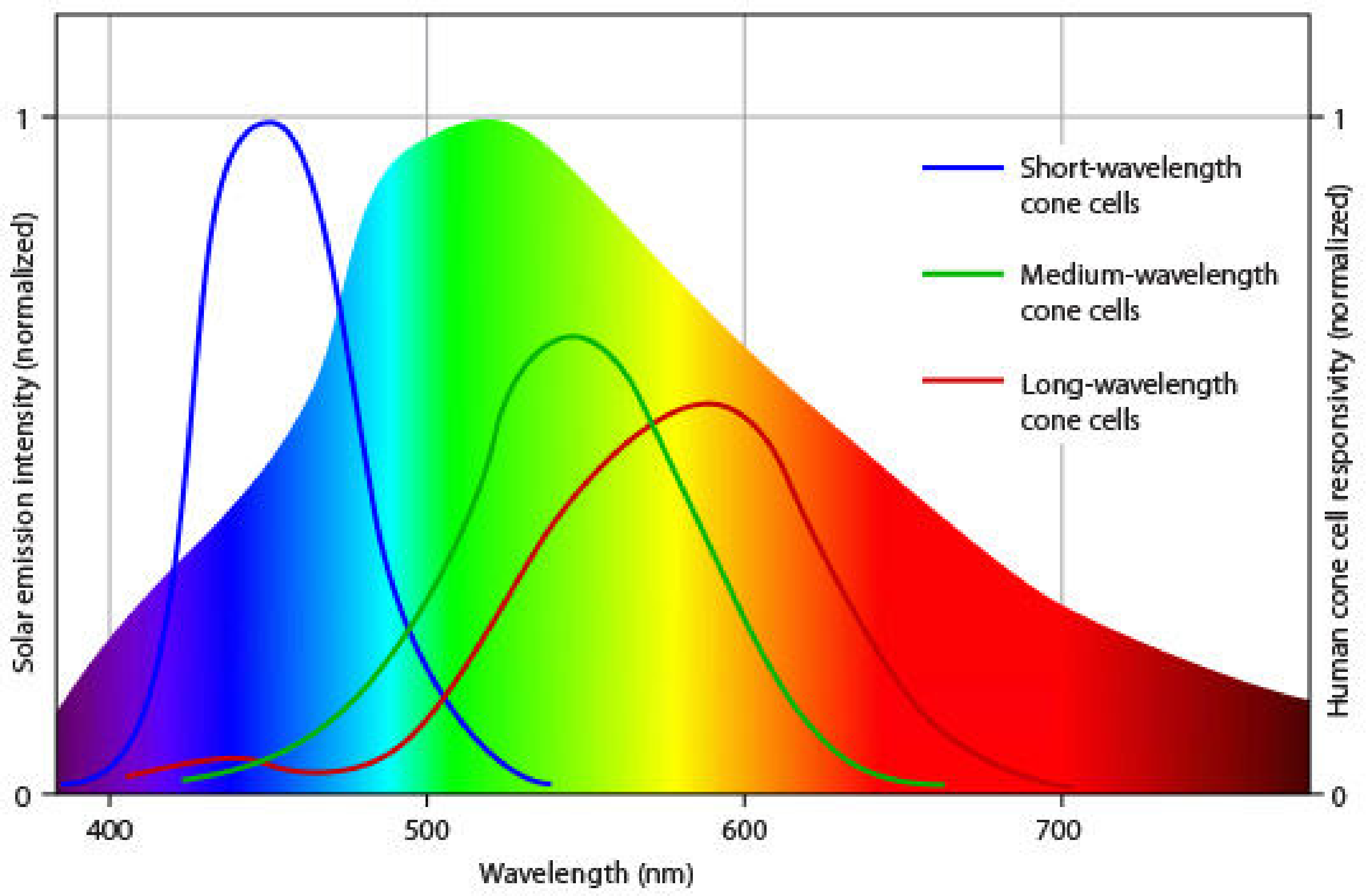
Figure 1.18. Vignetting effect in a two-lens system. The shaded part of the beam never reaches the second lens. Additional apertures and stops in a lens further contribute to vignetting.

人眼


巩膜
视网膜
睫状体
神经及
其外层
玻璃体腔
光轴
角膜
暗点
叶黄素
视轴
虹膜
黄斑
透镜
绒膜体


0.42 mm
H'
H
F'
F
20 mm
15 mm

视锥细胞响应曲线



http://weeklysciencequiz.blogspot.com

传感器

Figure 1.21. The first photograph on record, “la table servie”, obtained by Nicéphore Niepce in 1822. Reprinted from [Montel, 1972], p. 9.

CCD

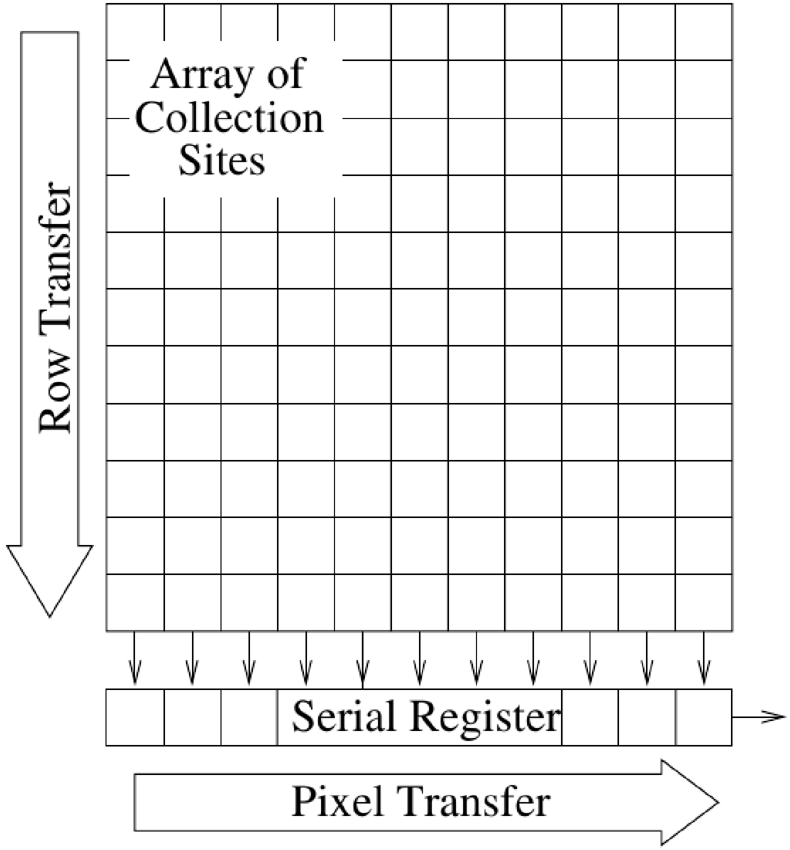


Figure 1.22. A CCD Device.

传感器模型

- $$I(r,c) = T\int_{\lambda}\int_{\boldsymbol{p}\in S(r,c)} E(\boldsymbol{p},\lambda)R(\boldsymbol{p})q(\lambda)\mathrm{d}\boldsymbol{p}\mathrm{d}\lambda$$

- $$D(r,c) = \gamma(N_I(r,c) + N_{\mathrm{DC}}(r,c) + N_B(,\mathrm{rc}) + R(r,c)) + Q(,r,c)$$