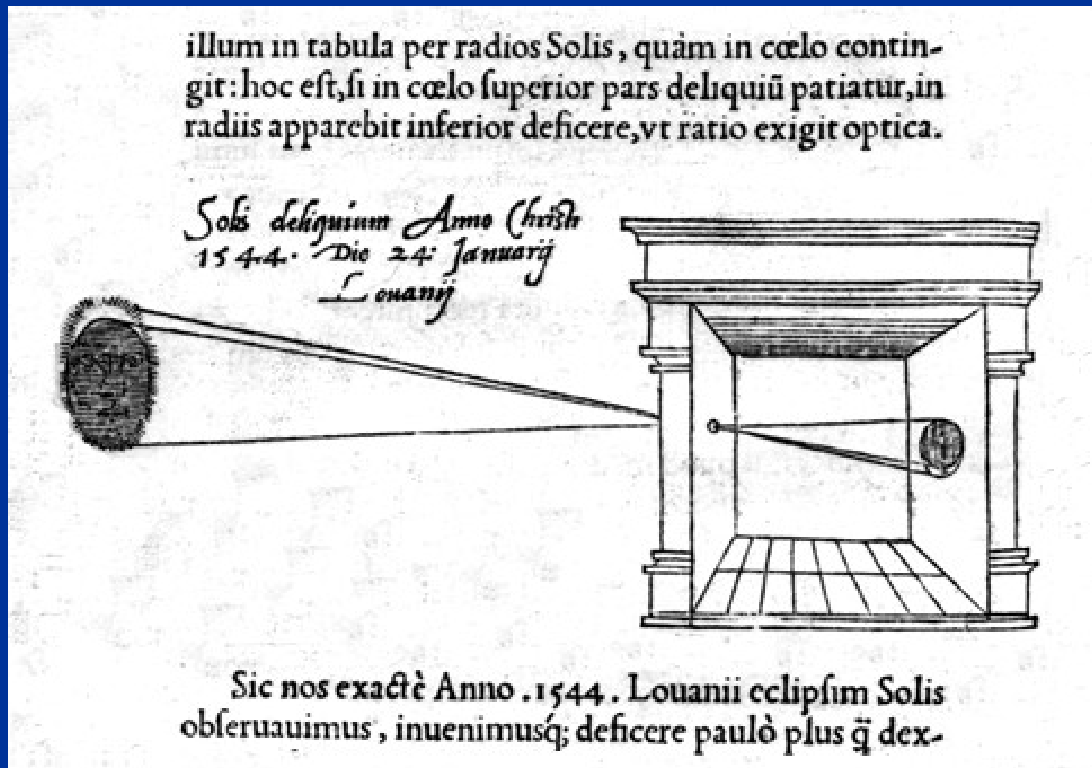
Image formation

Image Formation

- Vision infers world properties form images.
- How do images depend on these properties?
- Two key elements
  – Geometry
  – Radiometry
  – We consider only simple models of these

Camera Obscura



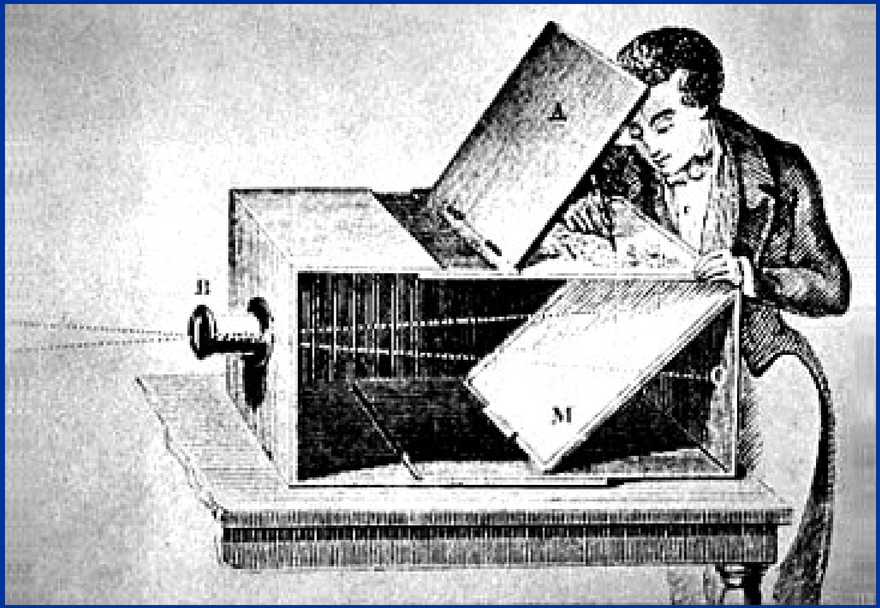
illum in tabula per radios Solis, quàm in cœlo contin-
git: hoc eſt, ſi in cœlo ſuperior pars deliquiũ patiatur, in
radiis apparebit inferior deficere, vt ratio exigit optica.

Sic nos exactè Anno .1544. Louanii eclipſim Solis
obſeruauimus, inuenimusq; deficere paulò plus q̃ dex-

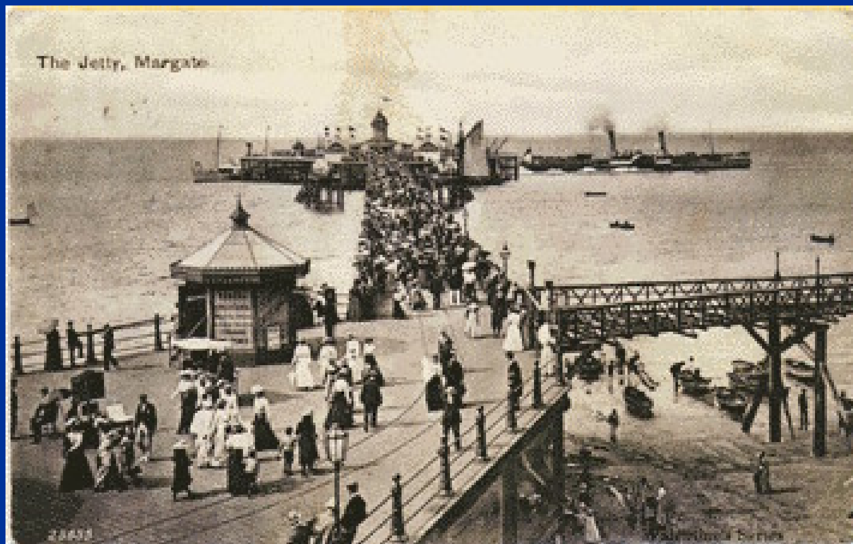
"When images of illuminated objects ... penetrate through a small hole into a very dark room ... you will see [on the opposite wall] these objects in their proper form and color, reduced in size ... in a reversed position, owing to the intersection of the rays".

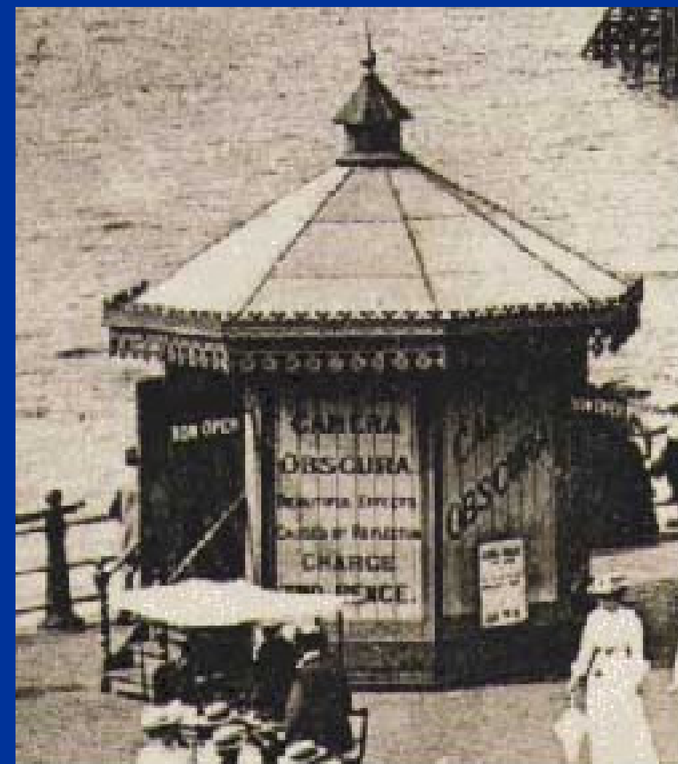
Da Vinci

http://www.acmi.net.au/AIC/CAMERA_OBSCURA.html (Russell Naughton)



- Used to observe eclipses (eg., Bacon, 1214-1294)
- By artists (eg., Vermeer).





Jetty at Margate England, 1898.

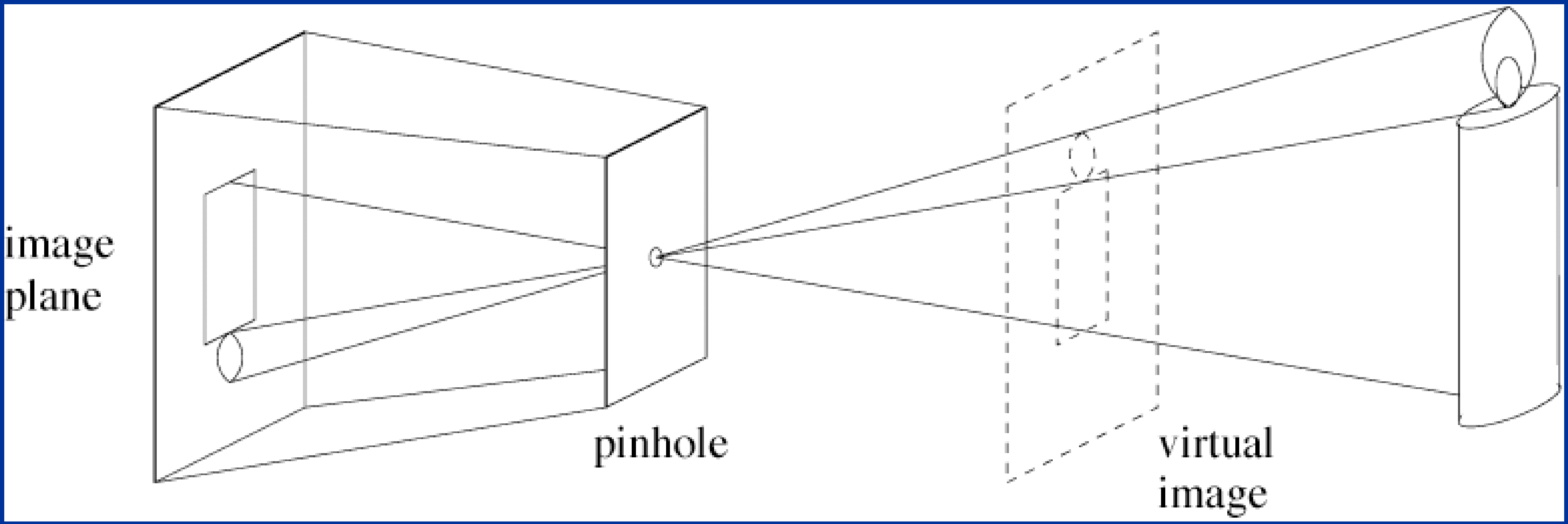
http://brightbytes.com/cosite/collection2.html (Jack and Beverly Wilgus)

Cameras

- First photograph due to Niepce
- First on record shown in the book - 1822

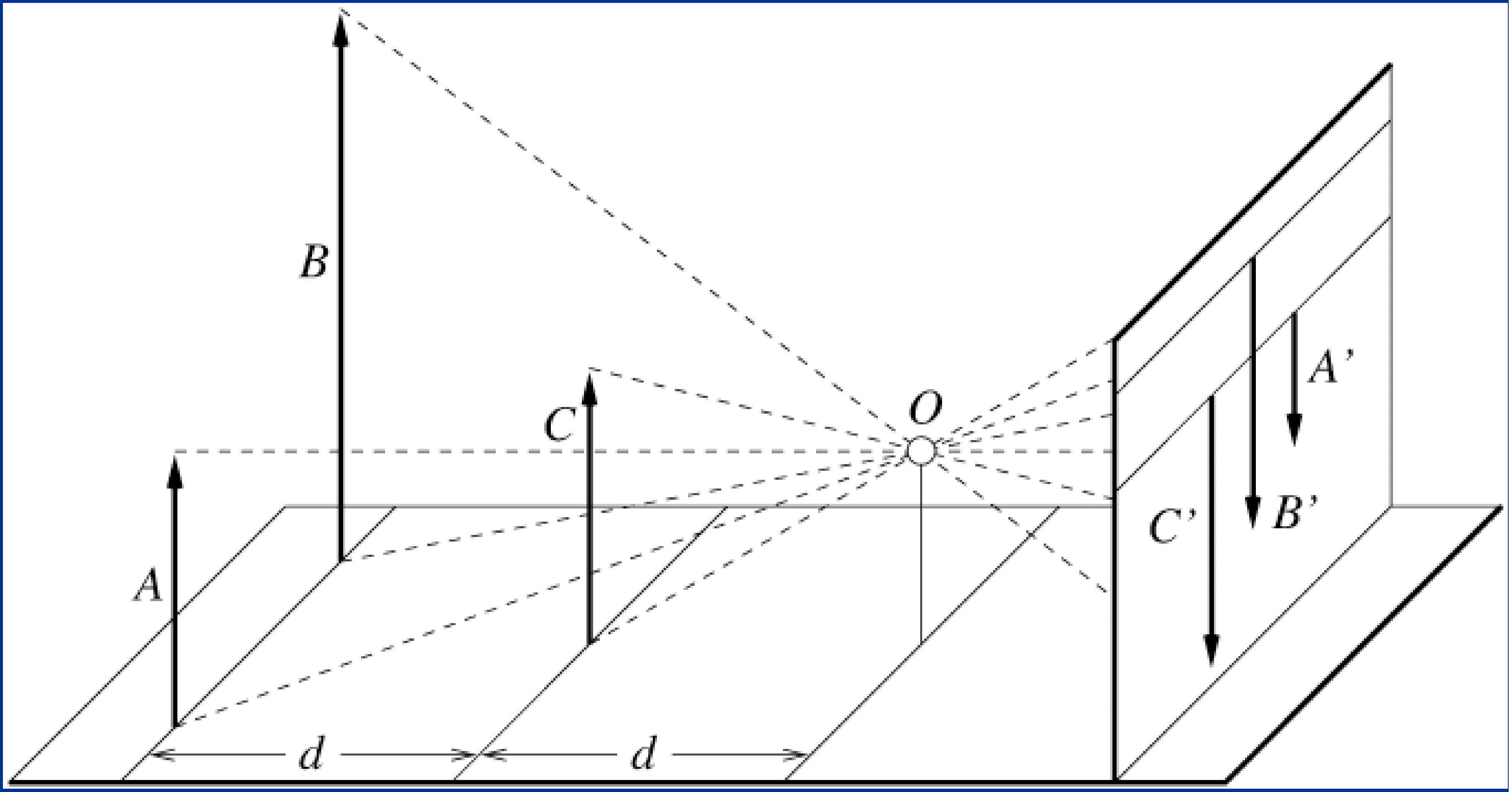
Pinhole cameras

- Abstract camera model - box with a small hole in it
- Pinhole cameras work in practice



(Forsyth & Ponce)

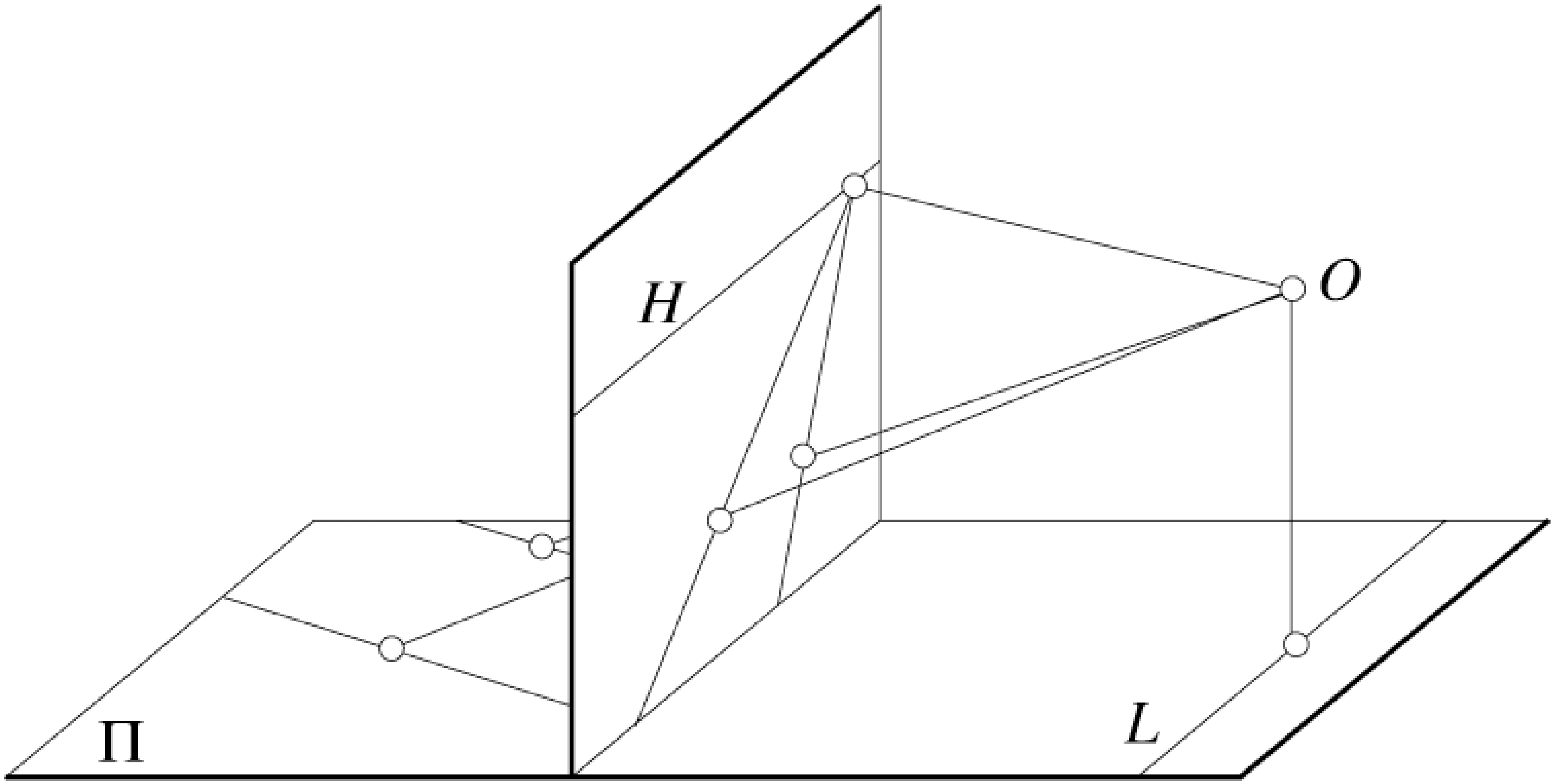
Distant objects are smaller



(Forsyth & Ponce)

Parallel lines meet

Common to draw image plane *in front* of the focal point.
Moving the image plane merely scales the image.



(Forsyth & Ponce)

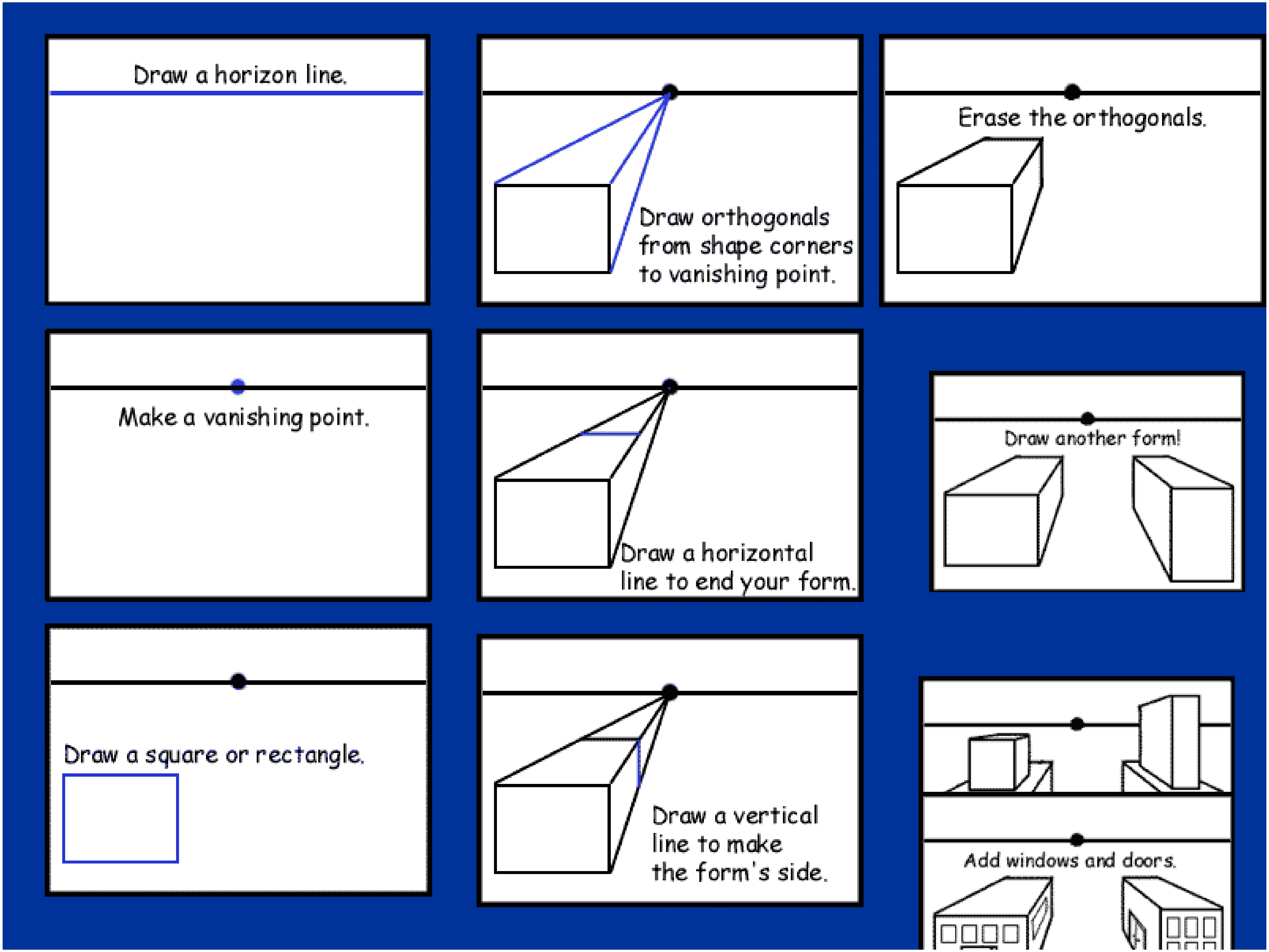
Vanishing points

- Each set of parallel lines meets at a different point
  - The *vanishing point* for this direction
- Sets of parallel lines on the same plane lead to *collinear* vanishing points.
  - The line is called the *horizon* for that plane

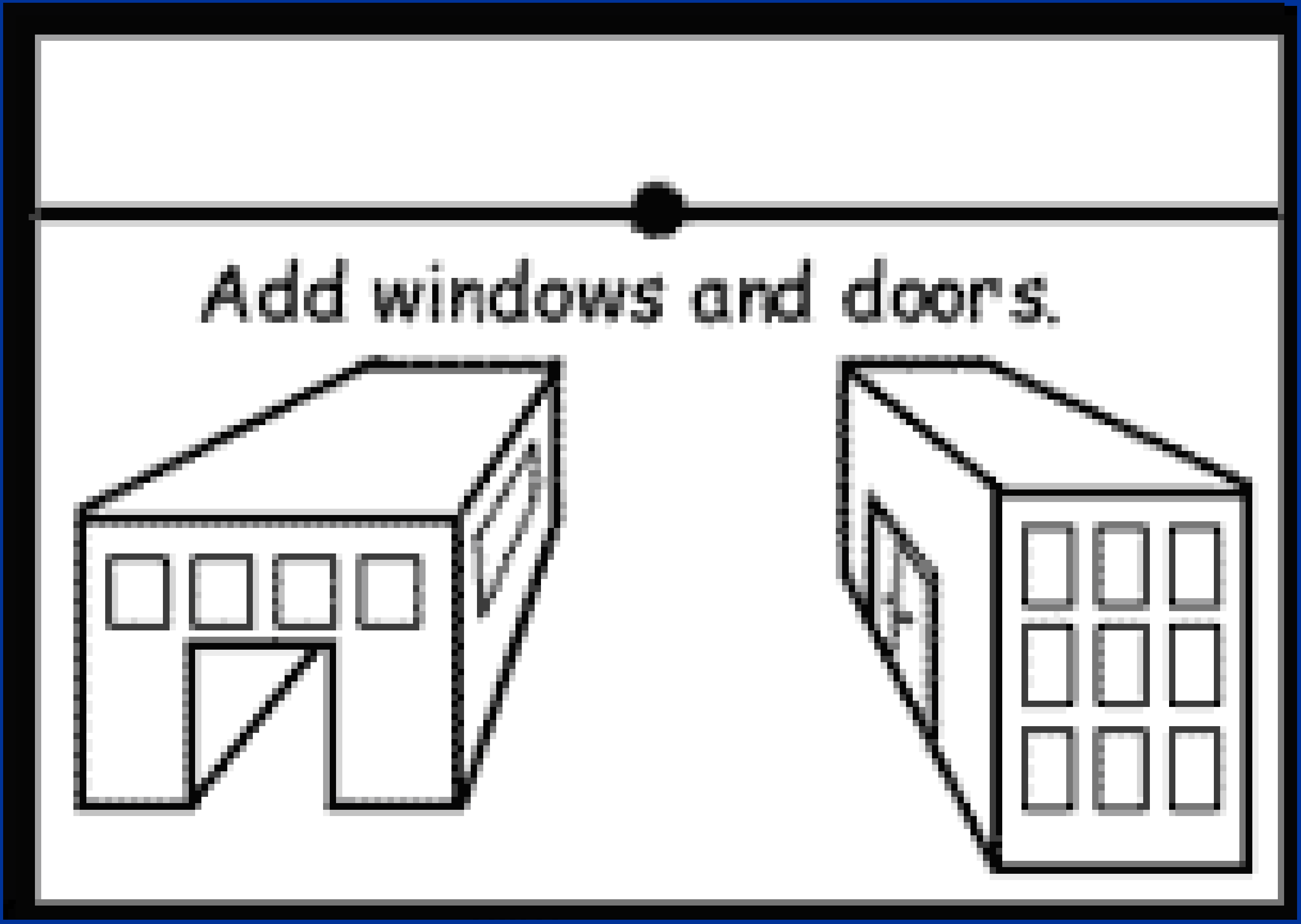
Properties of Projection

- Points project to points
- Lines project to lines
- Planes project to the whole image or a half image
- Angles are not preserved
- Degenerate cases
  - Line through focal point projects to a point.
  - Plane through focal point projects to line
  - Plane perpendicular to image plane projects to part of the image (with horizon).

Take out paper and pencil

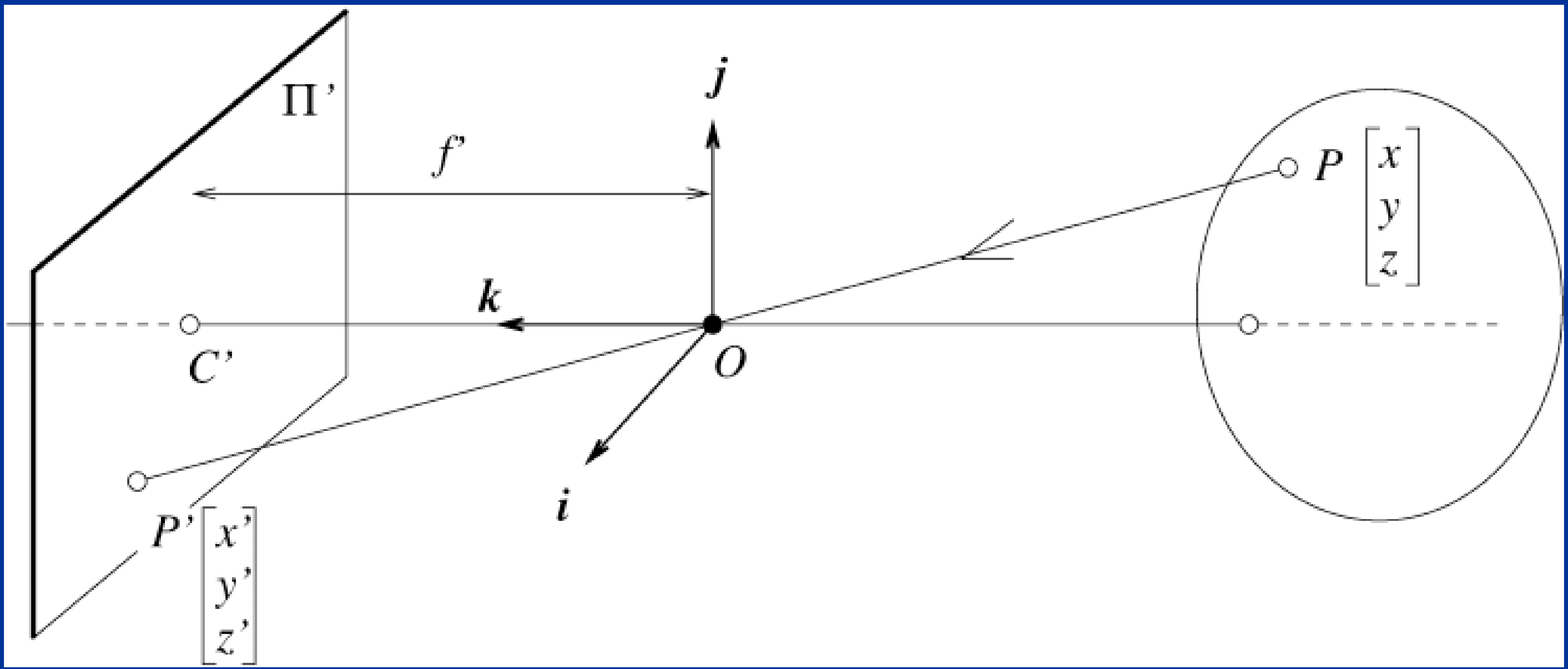


Draw a horizon line.
Make a vanishing point.
Draw a square or rectangle.
Draw orthogonals from shape corners to vanishing point.
Draw a horizontal line to end your form.
Draw a vertical line to make the form's side.
Erase the orthogonals.
Draw another form!
Add windows and doors.



http://www.sanford-artedventures.com/create/tech_1pt_perspective.html

The equation of projection



(Forsyth & Ponce)

The equation of projection

- Cartesian coordinates:
  - We have, by similar triangles, that

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

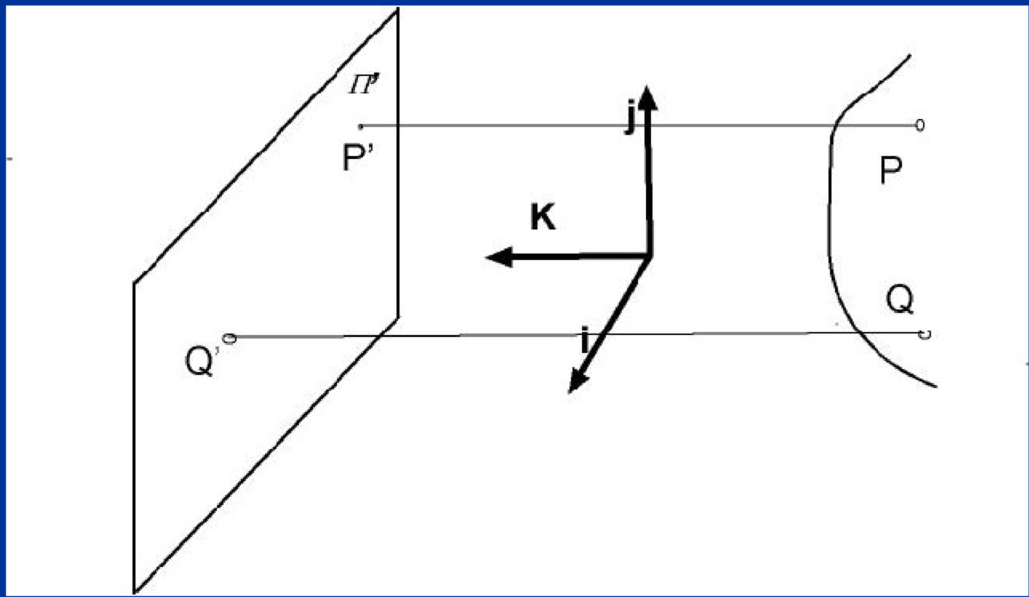
$$y' = f'\frac{y}{z}$$

$$(x, y, z) \rightarrow (f'\frac{x}{z}, f'\frac{y}{z}, f')$$

  - Ignore the third coordinate, and get

$$(x, y, z) \rightarrow (f'\frac{x}{z}, f'\frac{y}{z})$$

Orthographic projection

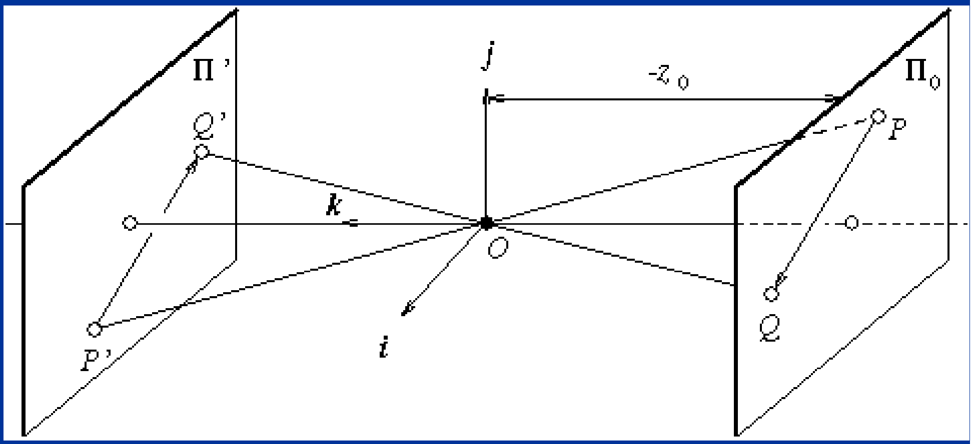


$$x' = x$$

$$y' = y$$

Weak perspective (scaled orthographic projection)

- Issue
  - perspective effects, but not over the scale of individual objects
  - collect points into a group at about the same depth, then divide each point by the depth of its group



(Forsyth & Ponce)

The Equation of Weak Perspective

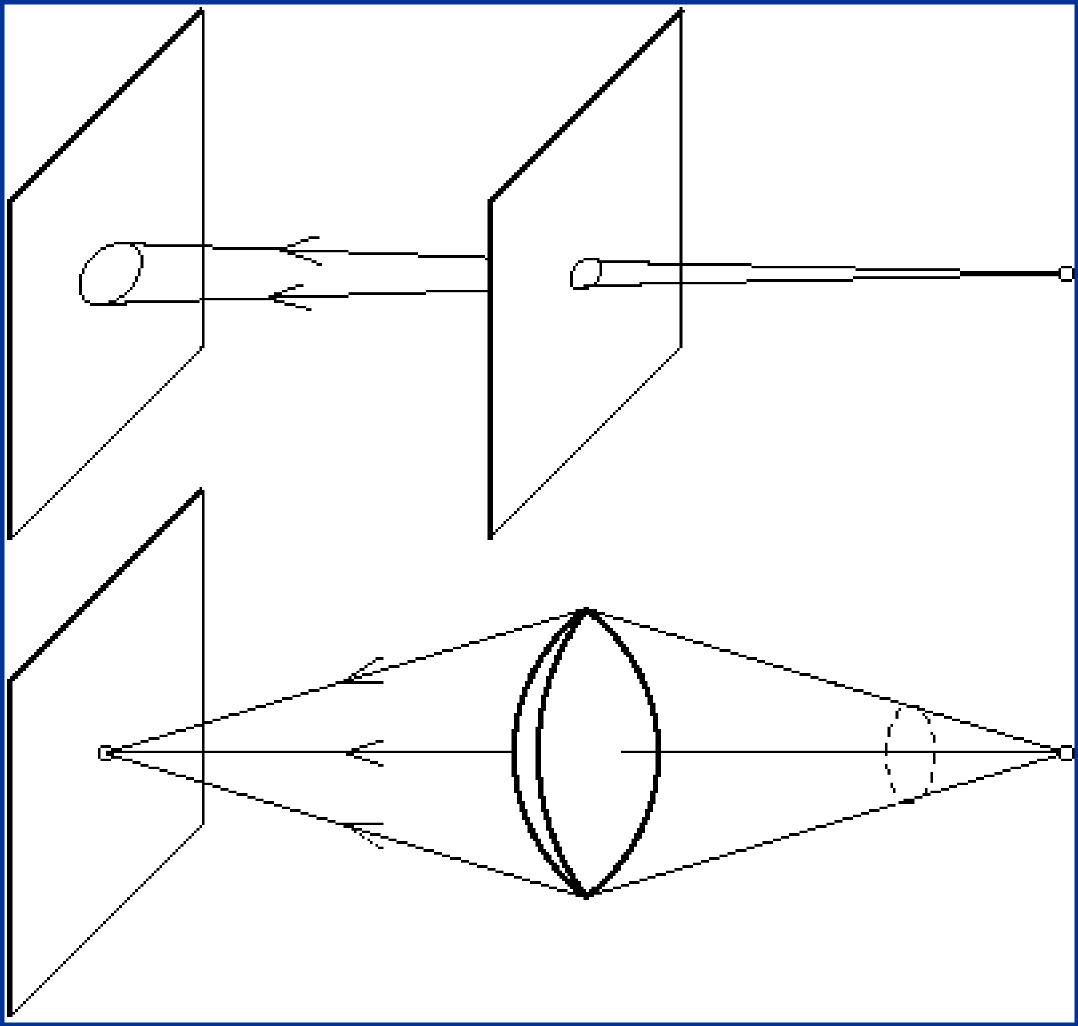
$$(x, y, z) \rightarrow s(x, y)$$

- *s* is constant for all points.
- Parallel lines no longer converge, they remain parallel.

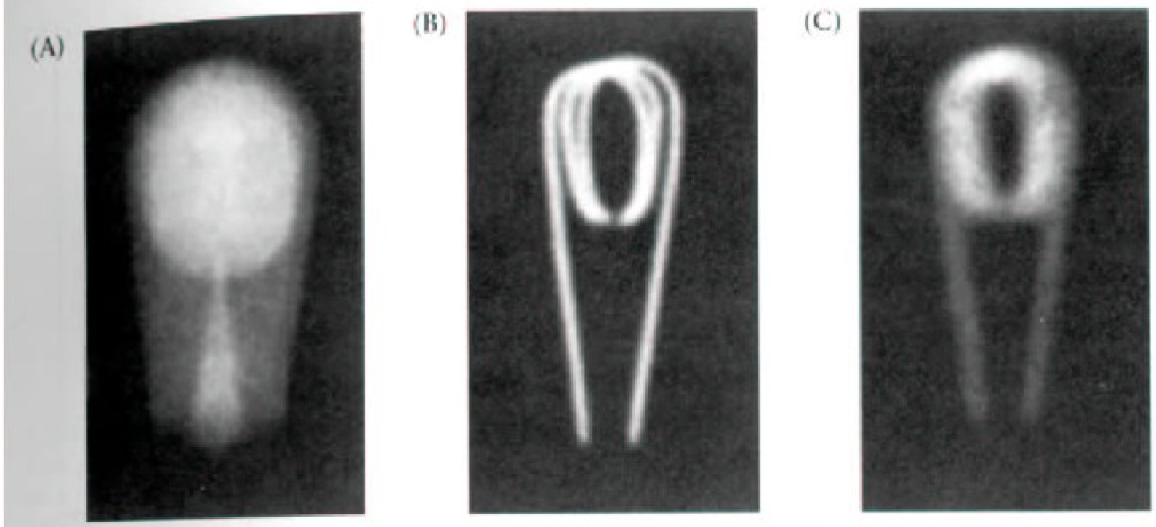
Pros and Cons of These Models

- Weak perspective much simpler math.
  - Accurate when object is small and distant.
  - Most useful for recognition.
- Pinhole perspective much more accurate for scenes.
  - Used in structure from motion.
- When accuracy really matters, must model real cameras.

Cameras with Lenses



(Forsyth & Ponce)



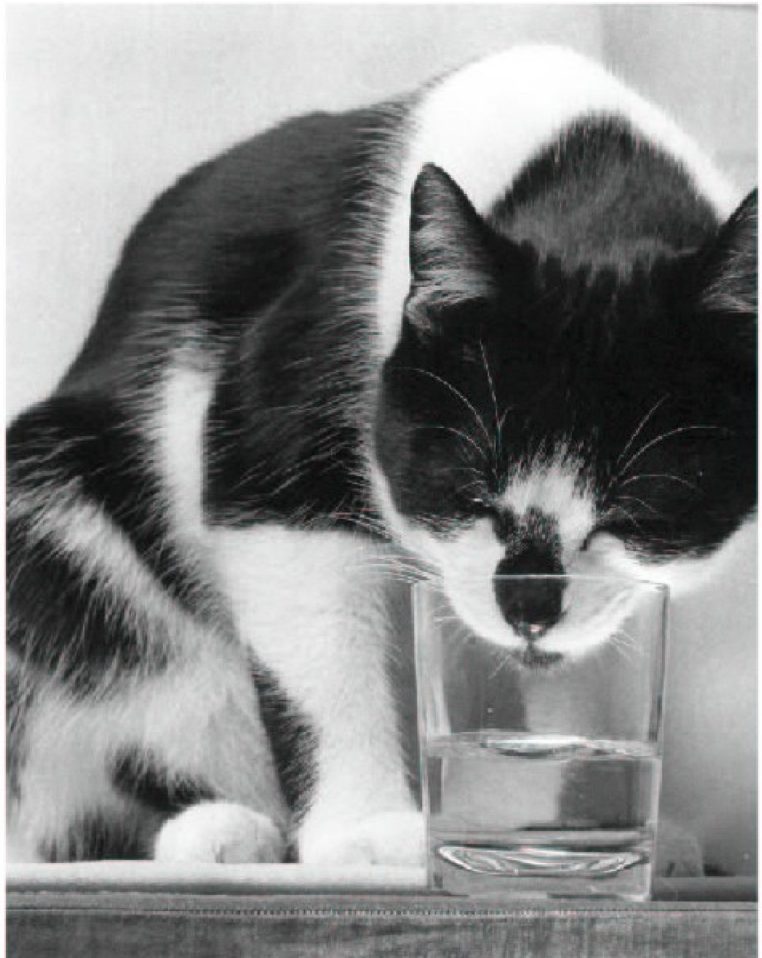
2.18 DIFFRACTION LIMITS THE QUALITY OF PINHOLE OPTICS. These three images of a bulb filament were made using pinholes with decreasing size. (A) When the pinhole is relatively large, the image rays are not properly converged, and the image is blurred. (B) Reducing the size of the pinhole improves the focus. (C) Reducing the size of the pinhole further worsens the focus, due to diffraction. From Ruechardt, 1958.

Wandell, Foundations of Vision, Sinauer, 1995

Interaction of light with matter

- Absorption
- Scattering
- Refraction
- Reflection
- Other effects:
  - Diffraction: deviation of straight propagation in the presence of obstacles
  - Fluorescence:absorbtion of light of a given wavelength by a fluorescent molecule causes reemission at another wavelength

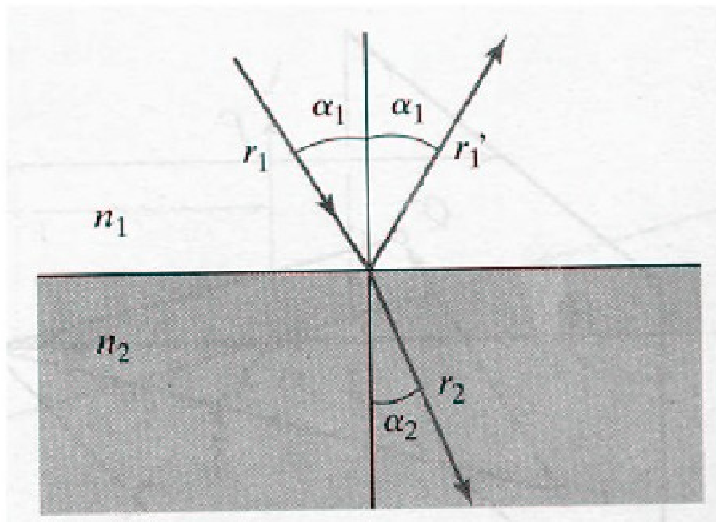
Water glass refraction



http://data.pg2k.hd.org/_exhibits/natural-science/cat-black-and-white-domestic-short-hair-DSH-with-nose-in-glass-of-water-on-bedside-table-tweaked-mono-1-AJHD.jpg

Refraction

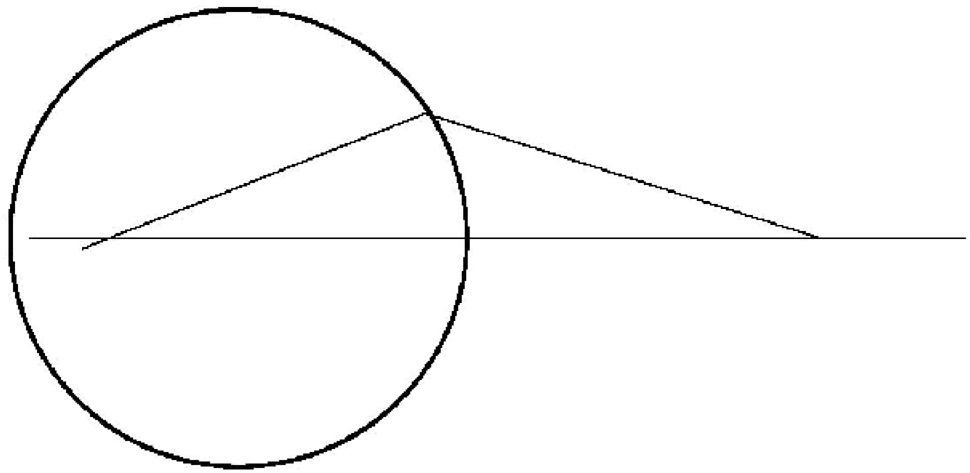
Snell's law



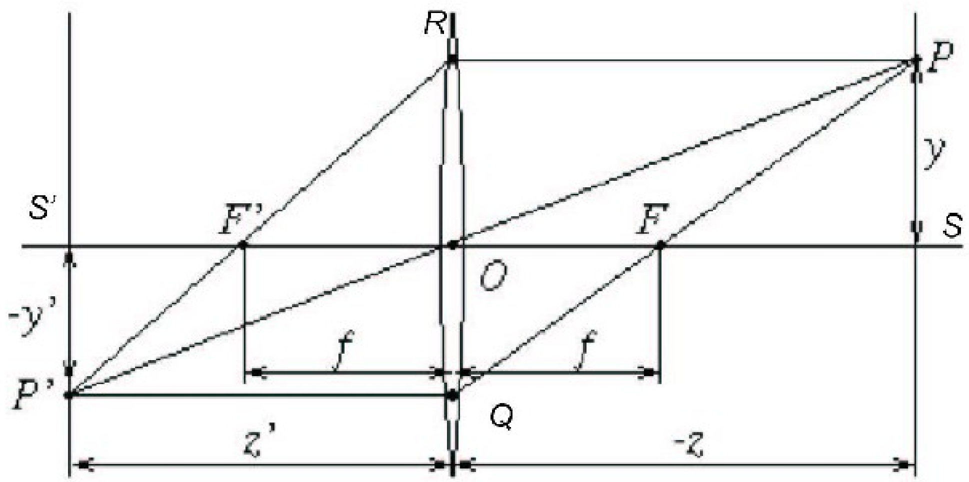
$$n_1 \sin(\alpha_1) = n_2 \sin(\alpha_2)$$

n1, *n2*: indexes of refraction

Spherical lens



The thin lens, first order optics



Similar triangles <P’F’S’>,<ROF’> and <PSF><QOF> →

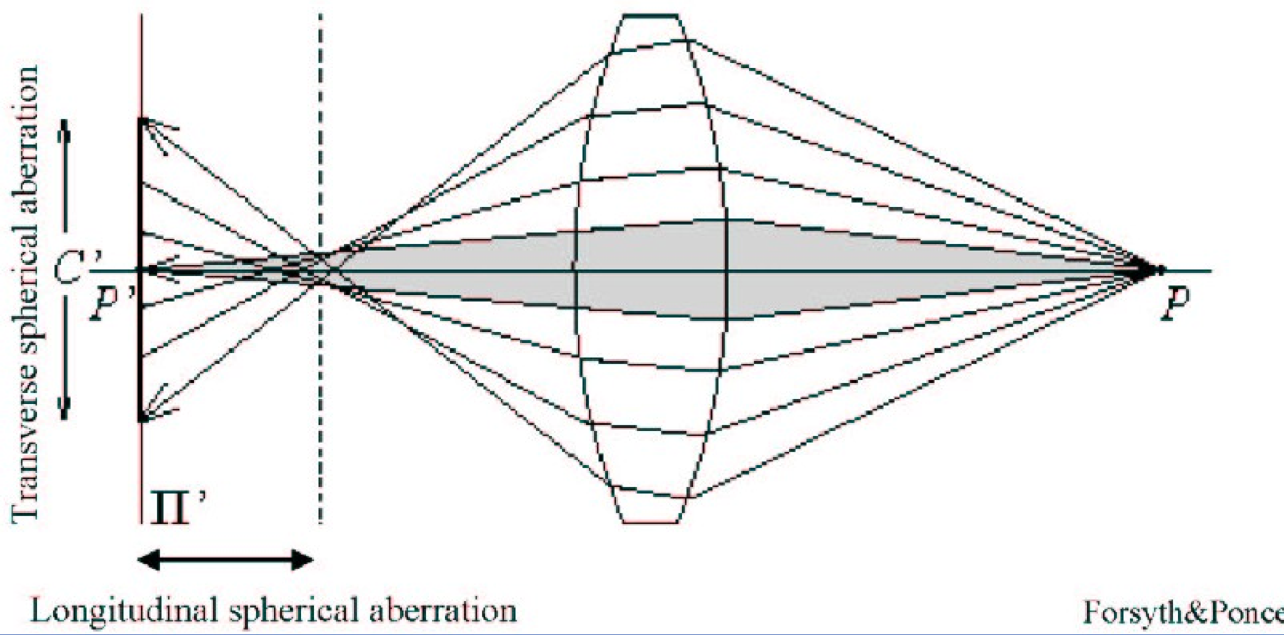
$$(z'-f)(-z-f)=f^2$$

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

Assumptions for thin lens equation

- Lens surfaces are spherical
- Incoming light rays make a small angle with the optical axis
- The lens thickness is small compared to the radii of curvature
- The refractive index is the same for the media on both sides of the lens

Spherical aberration (from 3rd order optics



Other aberrations

- Astigmatism: unevenness of the cornea
- Distortion : different areas of lens have different focal length
- Coma : point not on optical axis is depicted as asymmetrical comet-shaped blob
- Chromatic aberration

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