Computer Vision

1. Camera

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Outline

- Pinhole cameras
- Cameras with lenses
- Human eyes

Textbook:

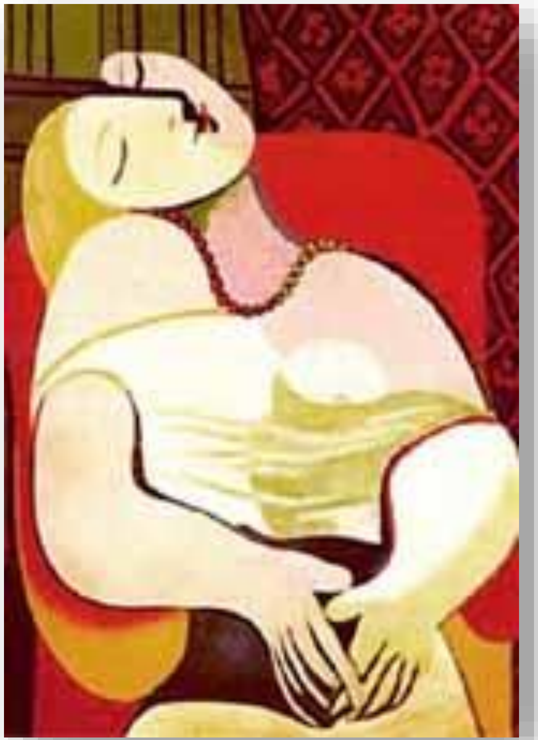
• David A. Forsyth and Jean Ponce, Computer Vision: A Modern Approach, Prentice Hall, New Jersey, (1st Ed. 2003, 2nd Ed. 2012) .

Some contents are from the reference lecture notes:

• Prof. D.A. Forsyth, Computer Vision, UIUC.
• Prof. T. Darrell, Computer Vision and Applications, MIT.
• Prof. J. Rehg, Computer Vision, Georgia Inst. of Tech.
• Prof. D. Lowe, Computer Vision, UBC, CA.

Which one is more realistic?

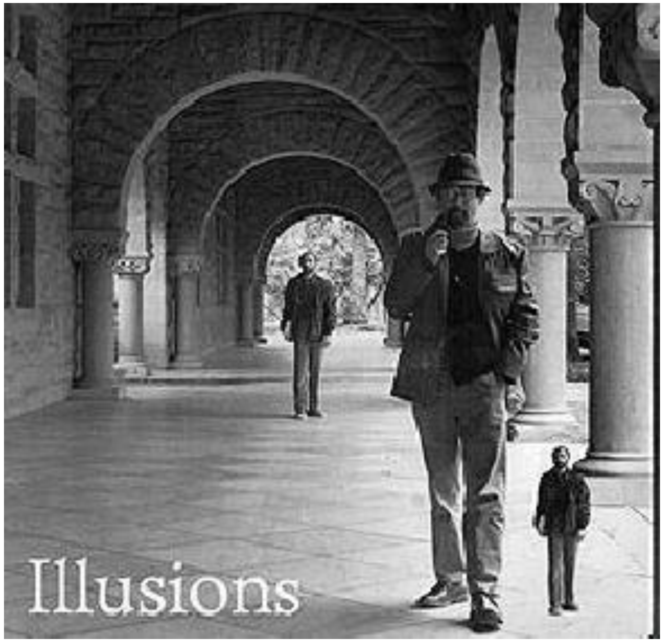
- How about these pictures?

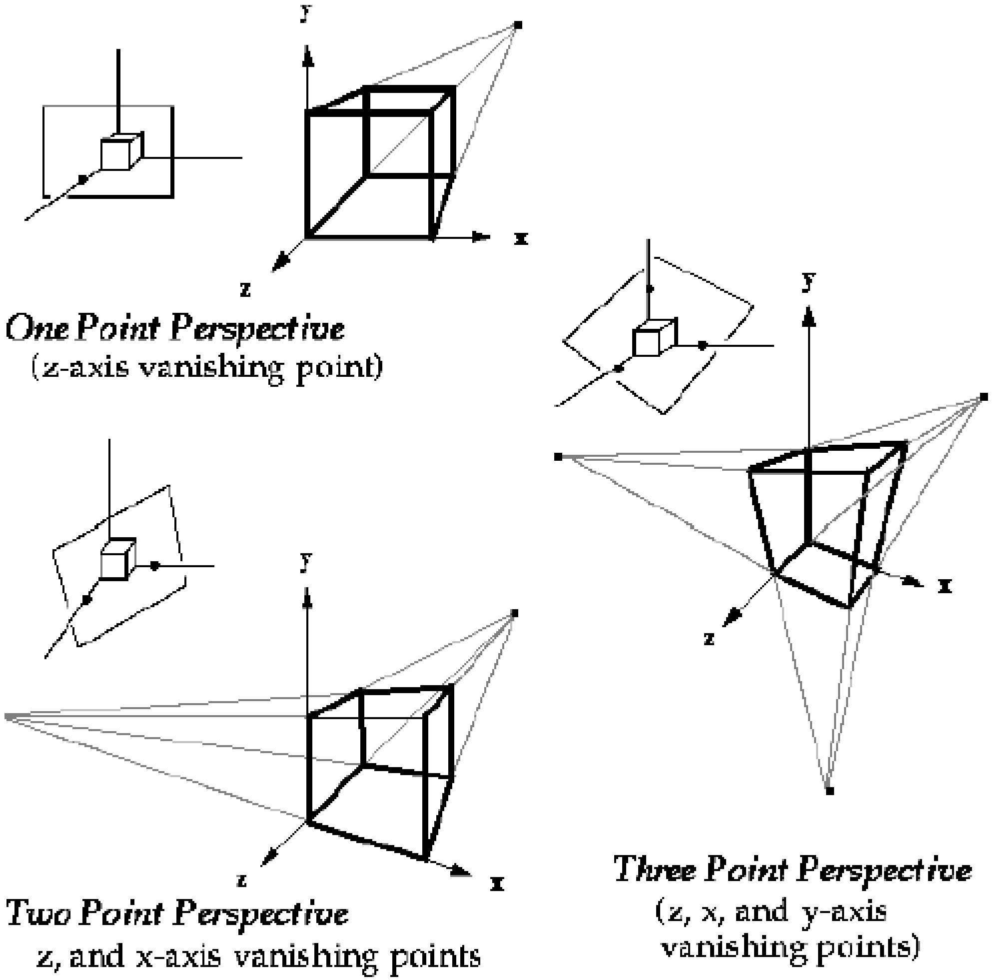


Picasso, The Dream, 1932
(Cubism)

Raphael, The School of Athens, around 1509-1511
(the Renaissance)

Vanishing points





Drawing with vanishing points

Examples of two vanishing points: http://www.alifetimeofcolor.com/main.taf?p=2,1,1,15

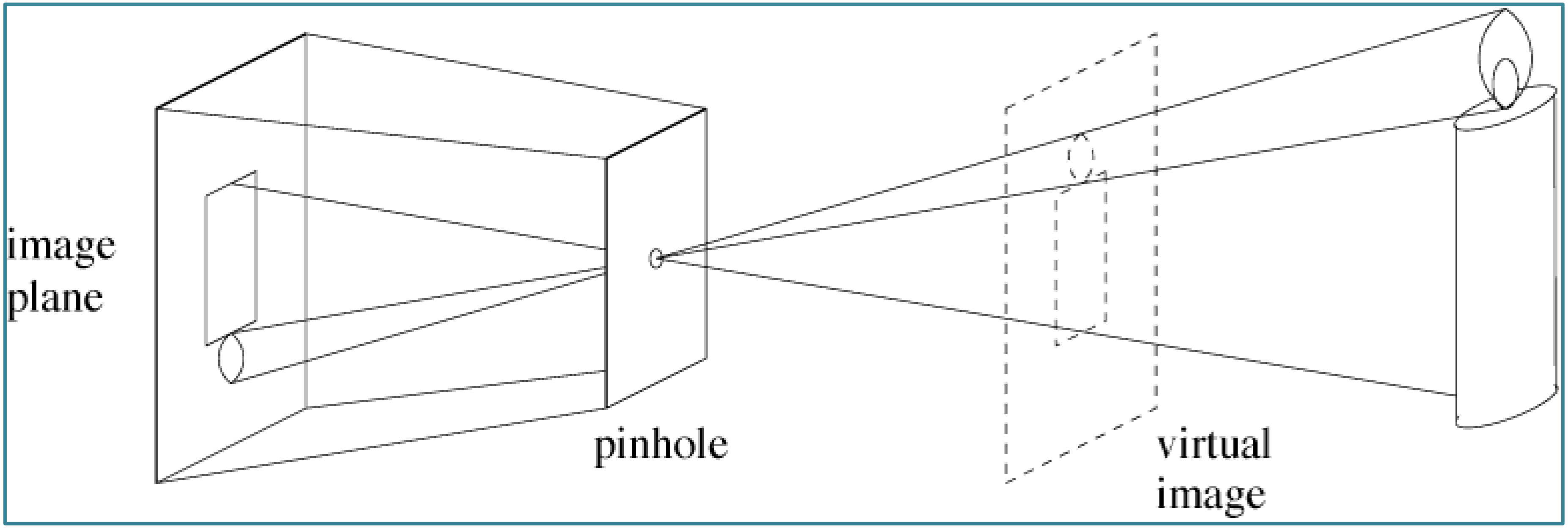
Camera obscura

- Camera Obscura, Reinerus Gemma-Frisius, 1544
  - (L. dark chamber), an aid to painting, consists of a darkened box and a small aperture where light passes.

http://www.acmi.net.au/AIC/CAMERA_OBSCURA.html

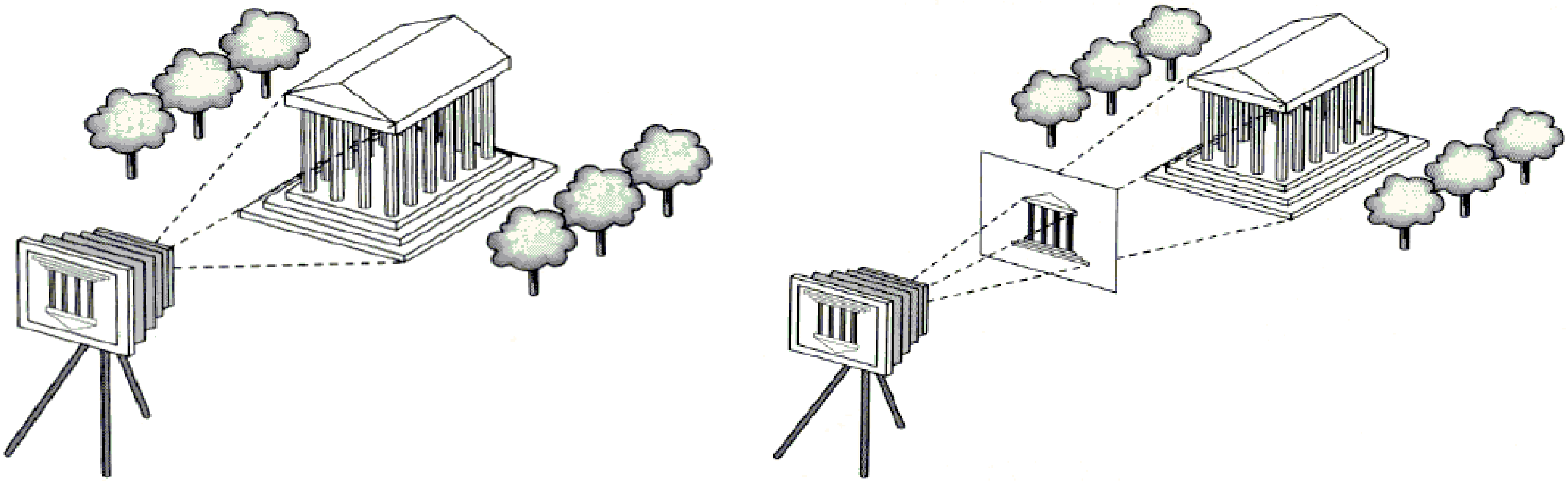
Pinhole model

- Pinhole camera – a box with a small hole in it.
  - Image is upside down.
    - (We usually use a virtual plane on the opposite side of the image plane)



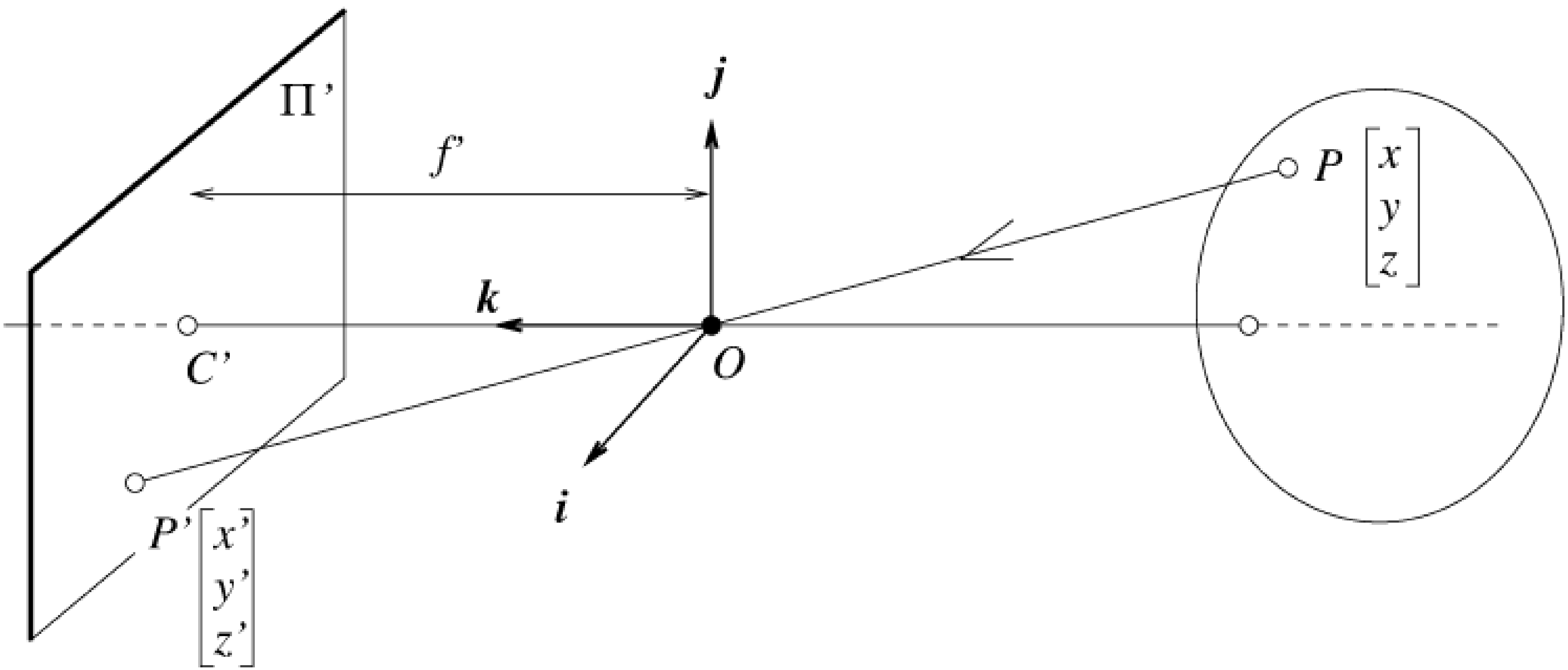
Perspective projection

- Taking photographing as an example.
- A camera records the lights on projective paths.



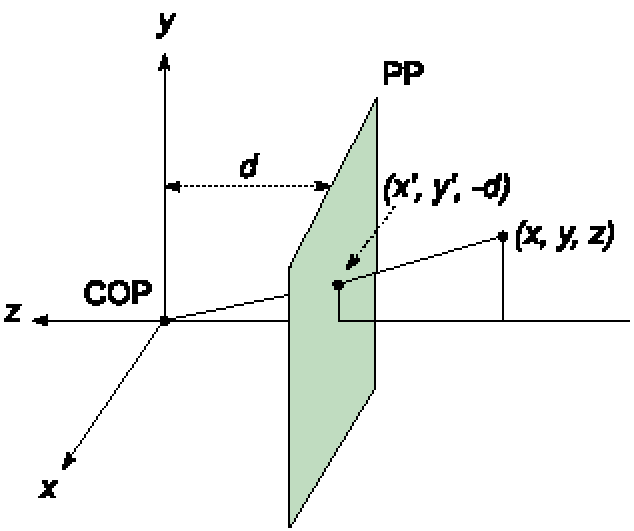
Perspective projection with the pinhole model

- $x' = f'(x/z)$; $y' = f'(y/z)$



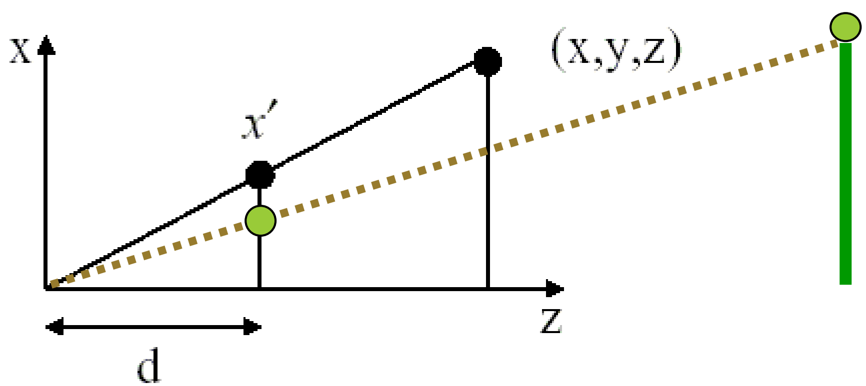
Perspective projection (cont.)

- Projection

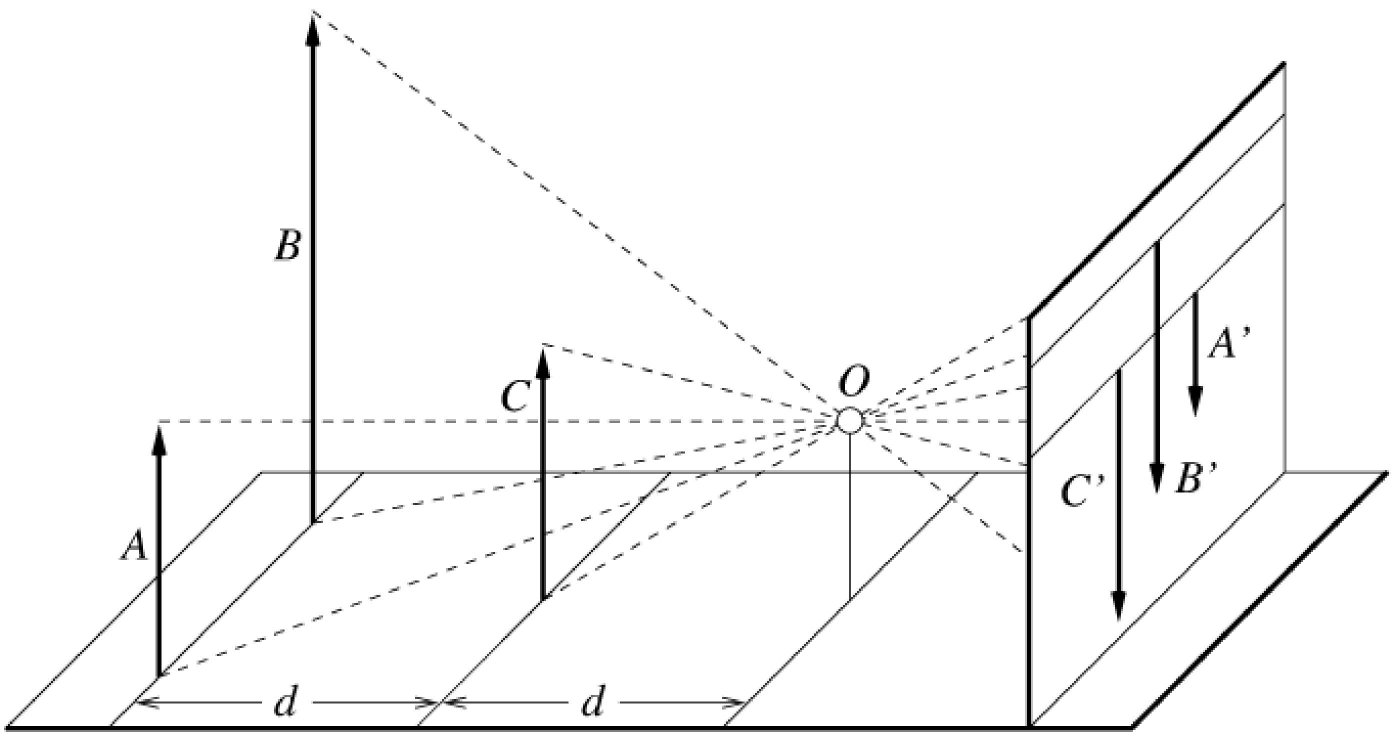


http://commons.wikimedia.org/wiki/
File:Taiwan_HighSpeedRail_Train_Business_Class_Car.JPG

Using similar triangles gives:

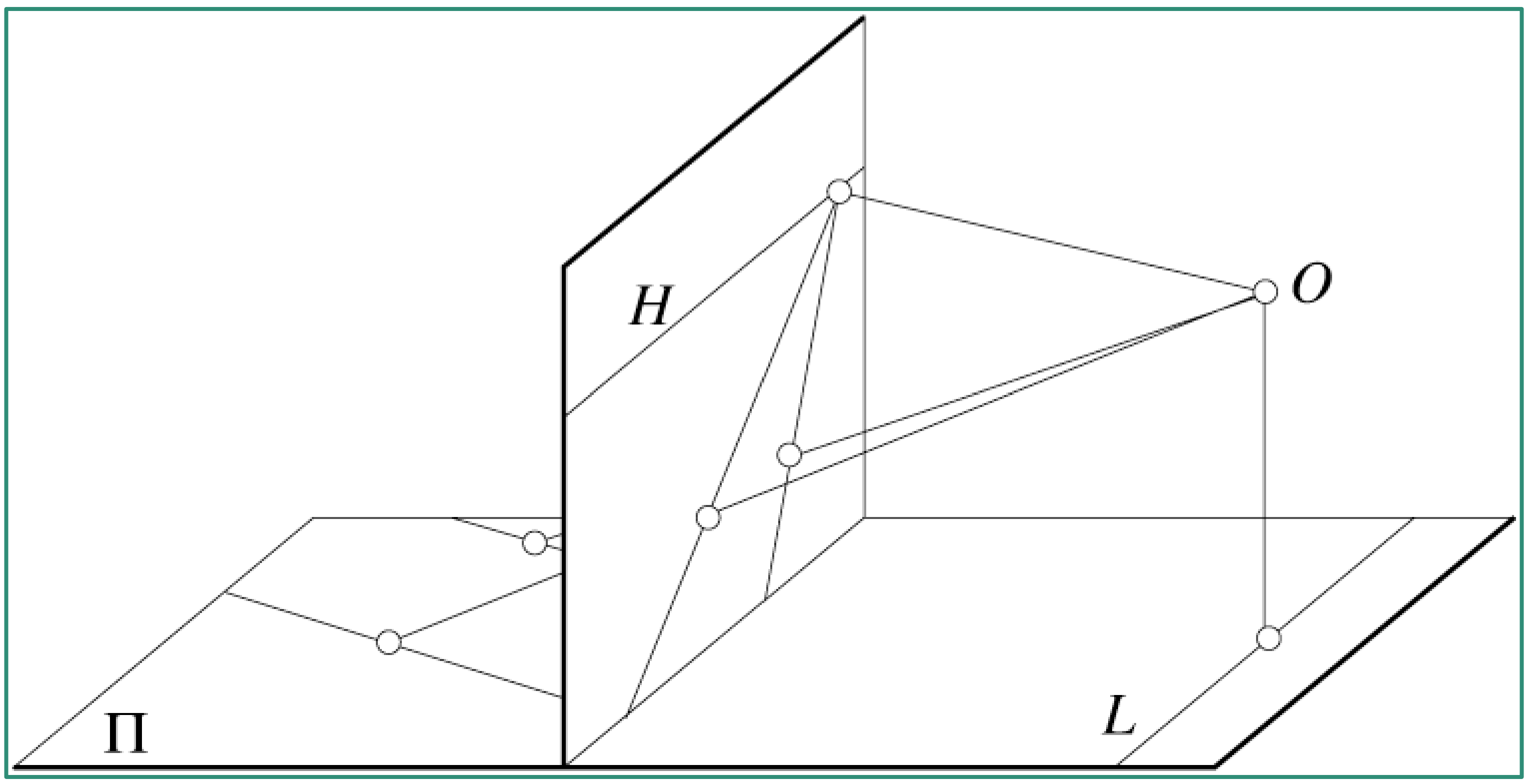


Distant objects are smaller



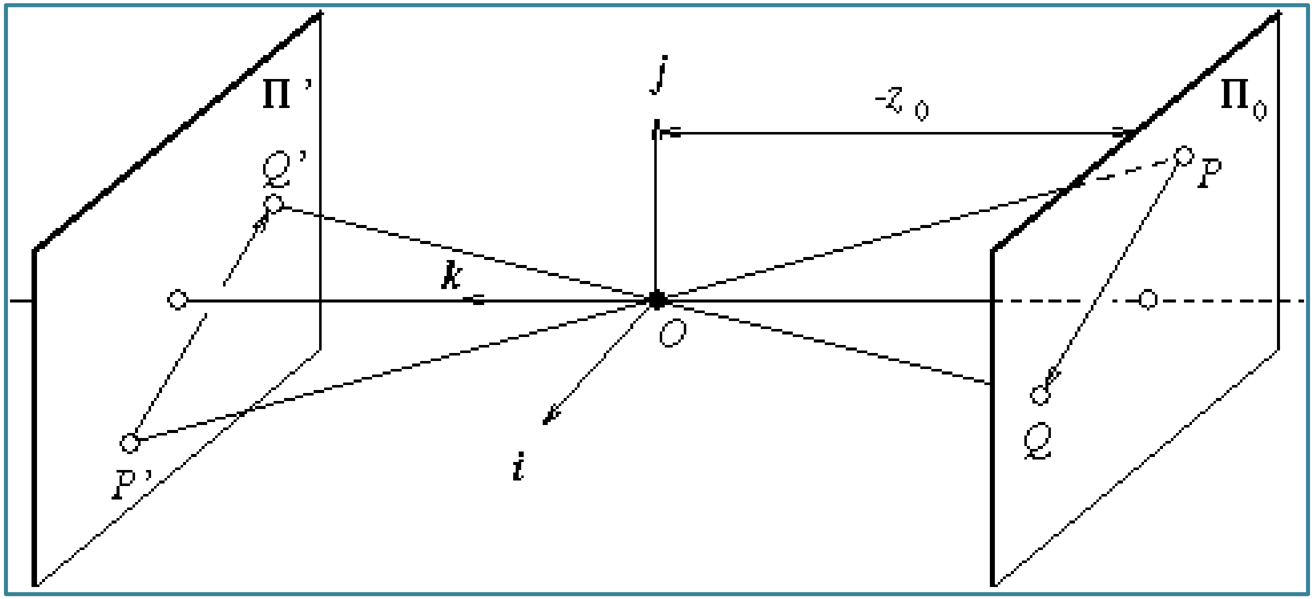
Vanishing point

- Each set of parallel lines meets at a different point.
- Sets of parallel lines on the same plane lead to collinear vanishing points, called the horizon for that plane.



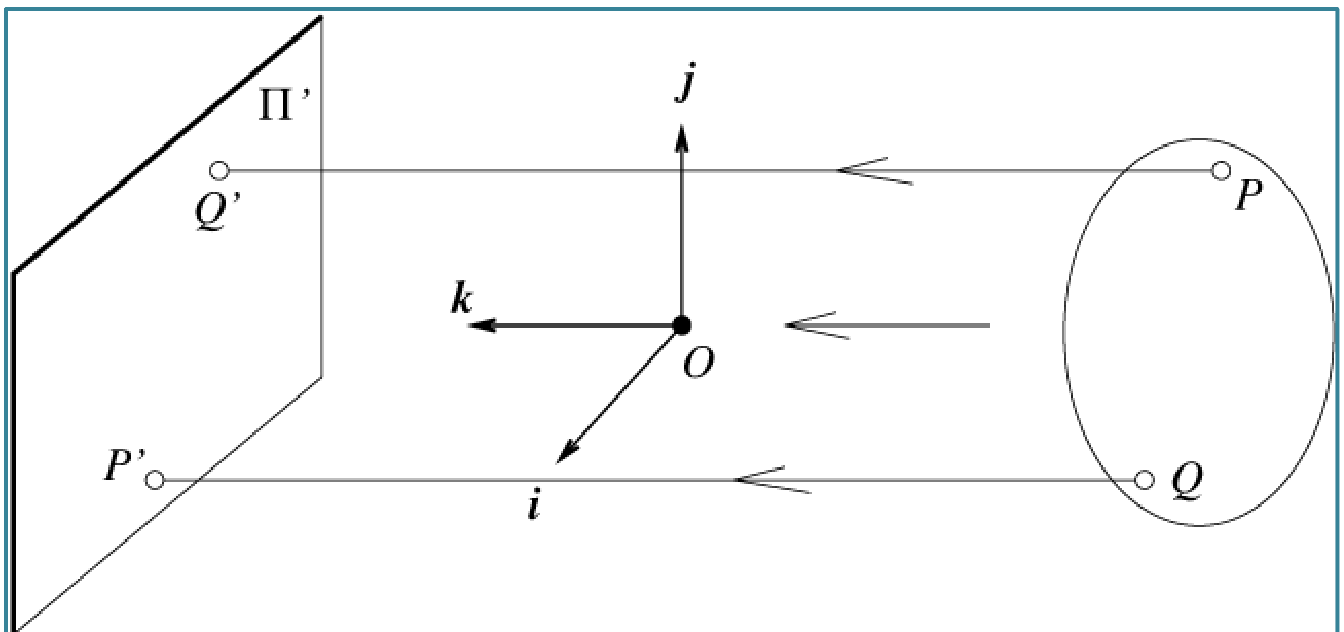
Weak-perspective

- When the scene depth is small relative to the average distance from the camera.
- All line segments in the plane Π_0 are projected with the same magnification.
  - Simple but incorrect.



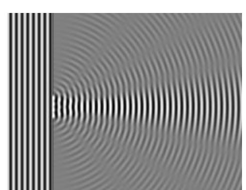
Orthographic projection

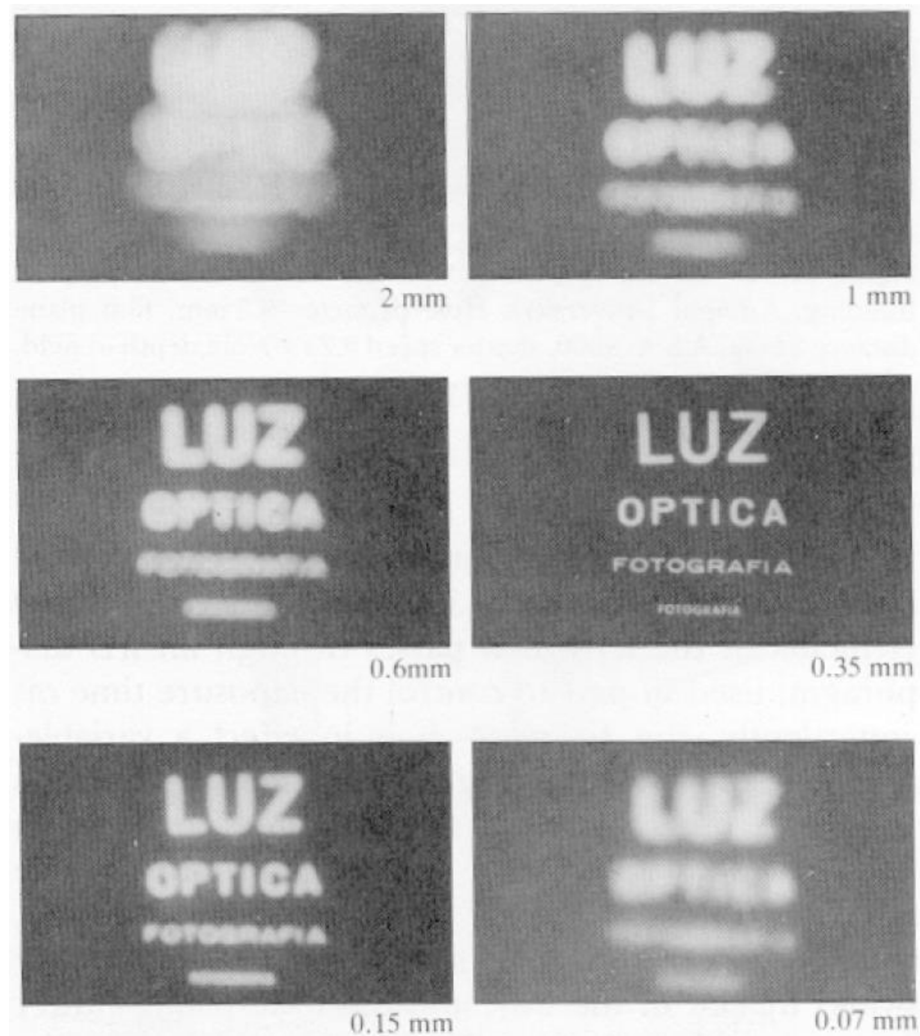
- $x' = x$
- $y' = y$



The problem

- Pinhole too big:
  - brighter, but blurred.
- Pinhole right size:
  - sharp, but dark.
- Pinhole too small:
  - blurred due to diffraction.

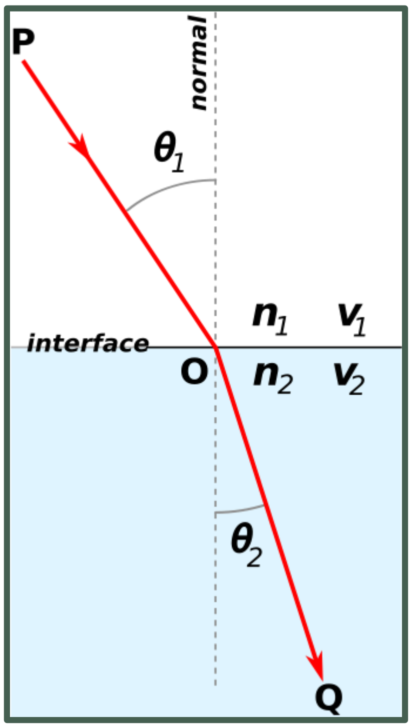


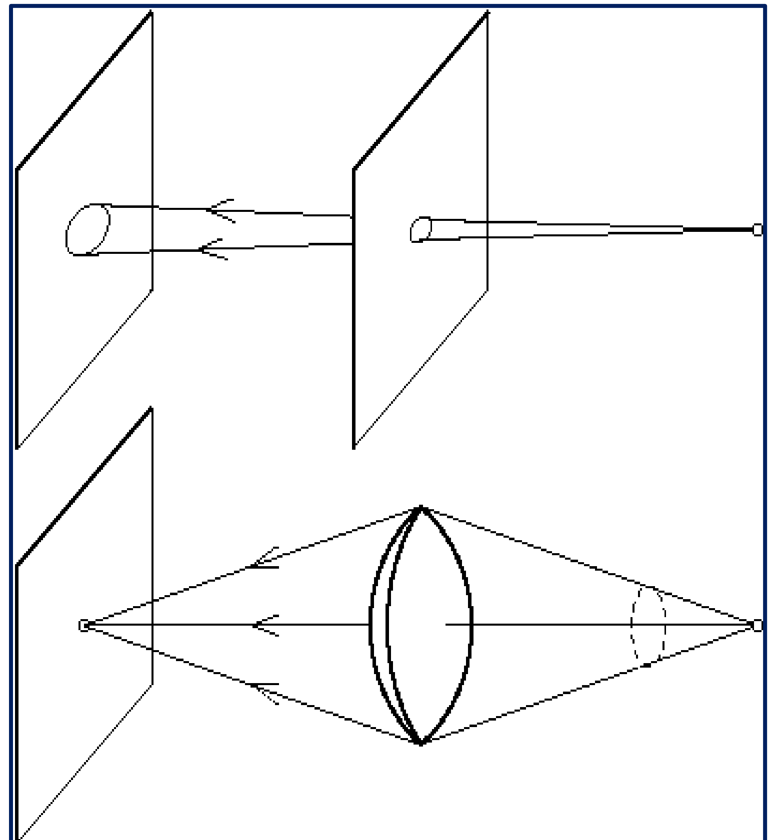


http://en.wikipedia.org/wiki/Diffraction

Cameras with lenses

- According to Snell's law:
  - $n_1 \sin\vartheta_1 = n_2 \sin\vartheta_2$

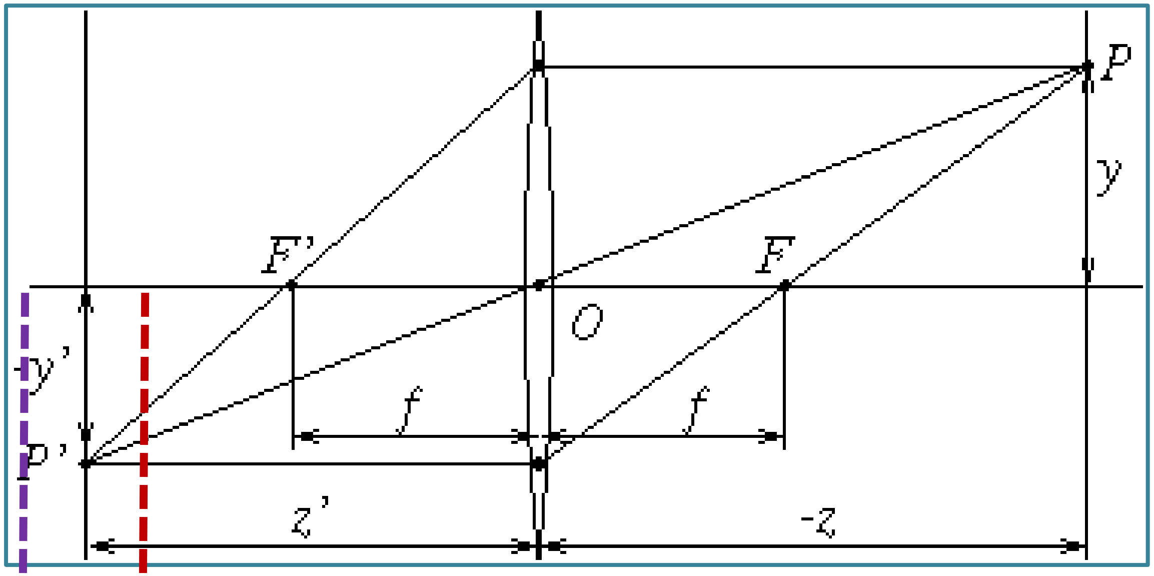




en.wikipedia.org/wiki/Snell's_law

Thin lens

- A lens follows the pinhole model for objects that are in focus.
- All rays through *P* also pass through *P'*, but only for points at -z: "depth of field".
  - The image becomes blurred if P is at a "wrong" distance.



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

$$z \rightarrow \infty \Rightarrow \frac{1}{z'} = \frac{1}{f}$$

Appendix: depth of field

Fig. from: https://www.vision-doctor.com/en/optical-basics/depth-of-field.html

https://en.wikipedia.org/wiki/Depth_of_field

Real lens

principal plane

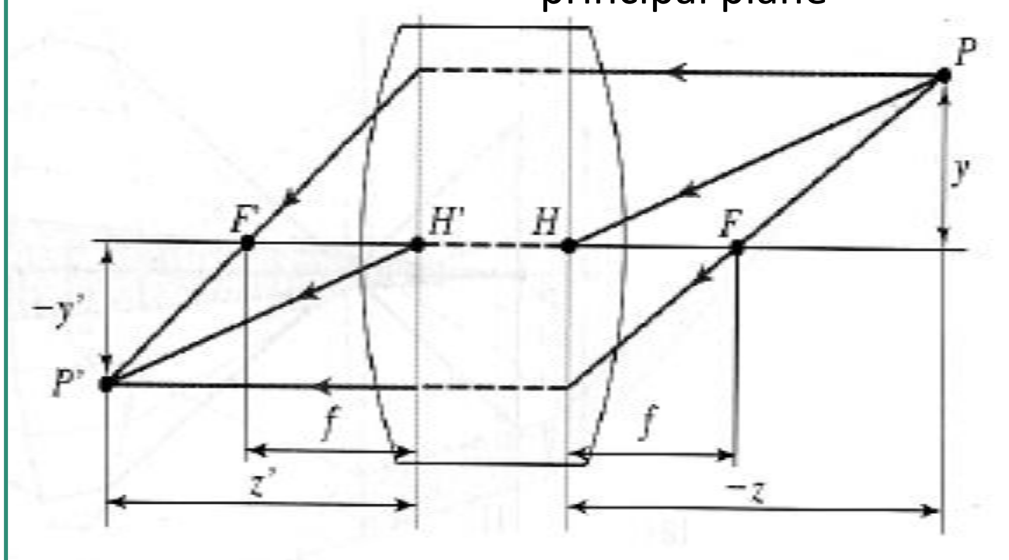
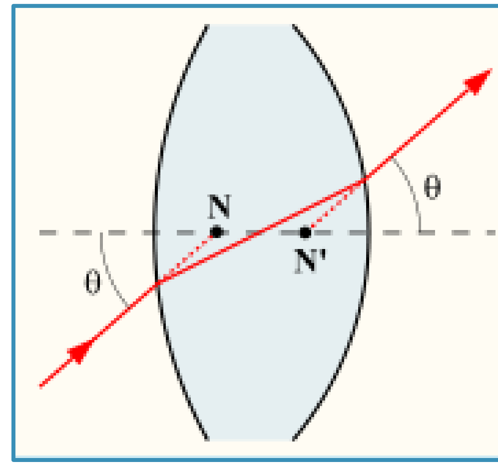


Figure 1.11 A simple thick lens with two spherical surfaces.



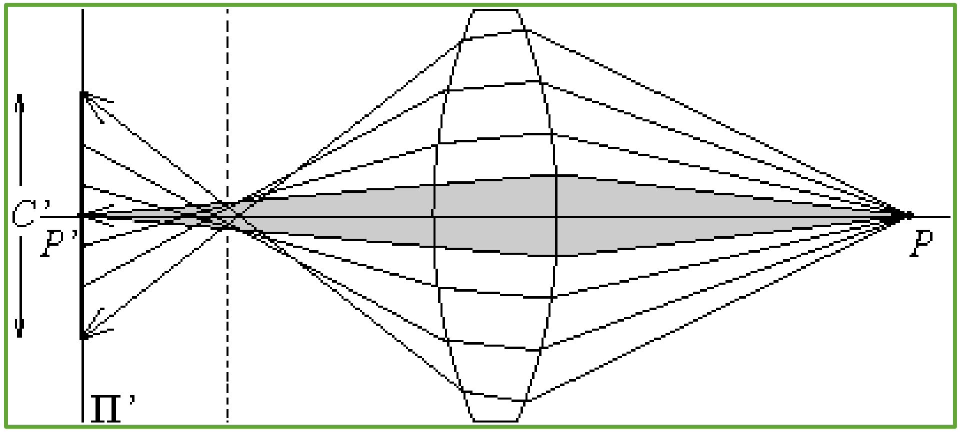
http://en.wikipedia.org/wiki/File:Cardinal-points-2.svg

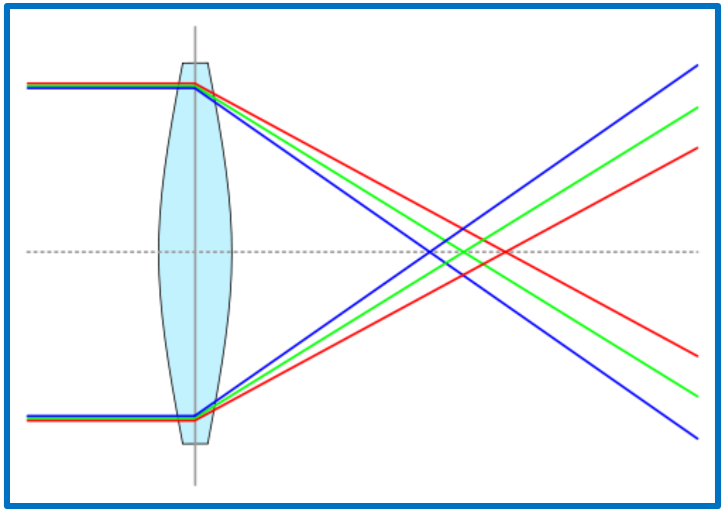
H: principal point

- Our equation based on small incident angle assumption; simple lenses suffer from a number of aberrations.

Aberrations

- Spherical aberration
- Chromatic aberration

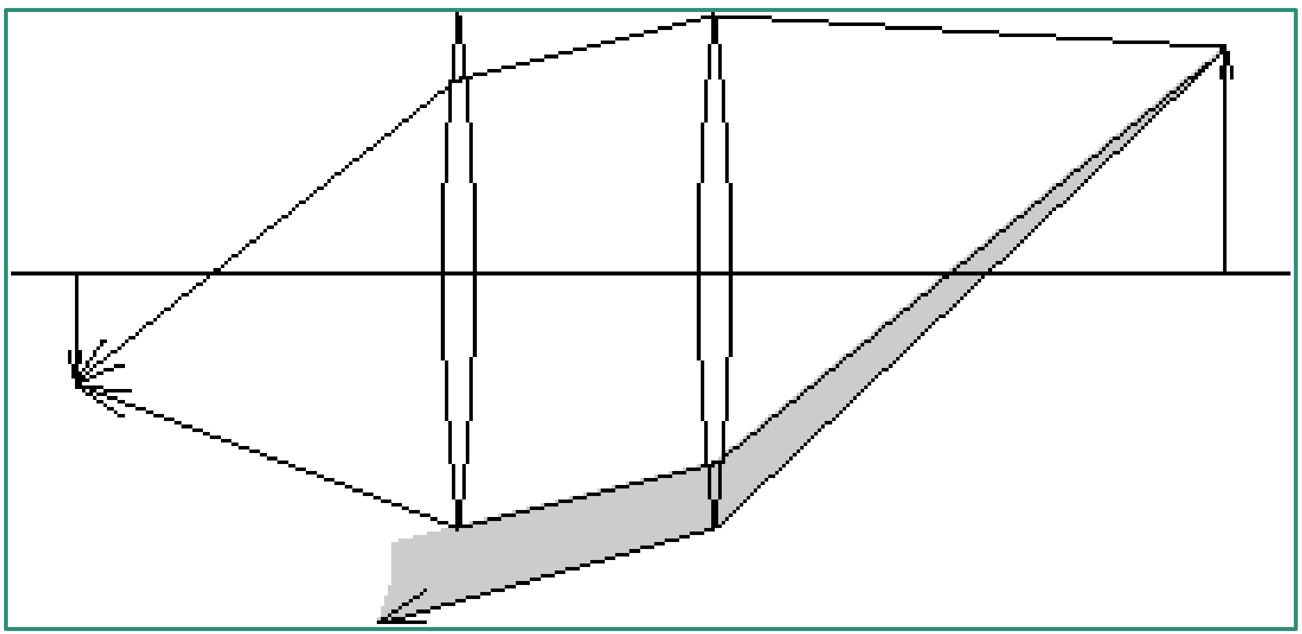




http://commons.wikimedia.org/wiki/File:Chromatic_aberration_(comparison).jpg

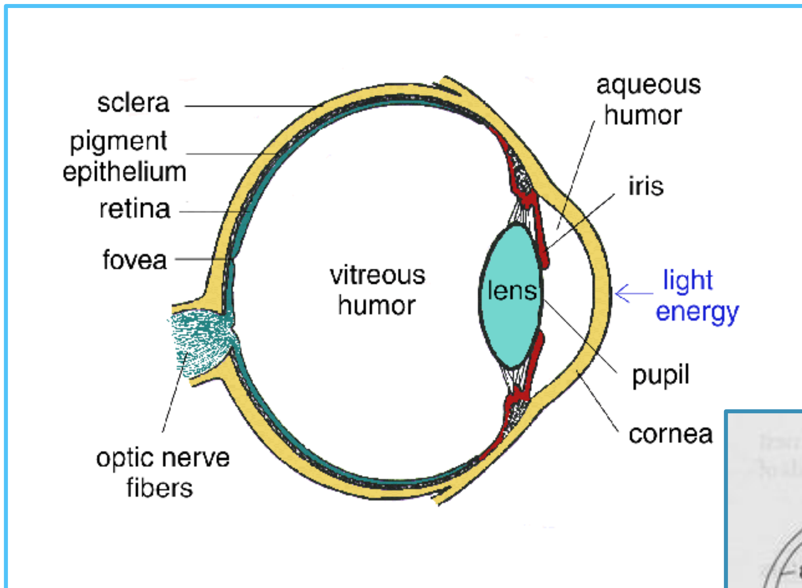
Compound lenses

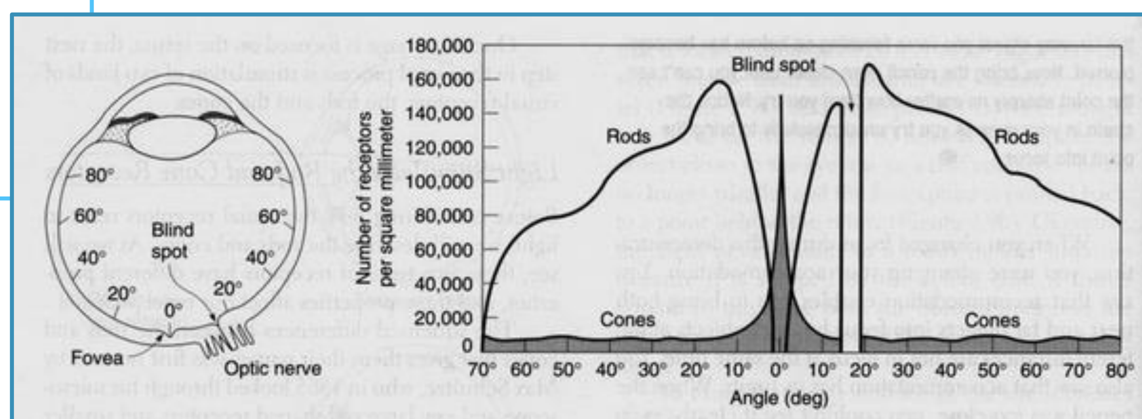
- Aberrations can be minimized by well-chosen lenses.
- Vignetting effect : the brightness to drop in the image periphery.



Human eye and refraction

- Large part of refraction occurs at air-cornea interface
- It is fine tune through the crystalline lens.





Ref: HCI lecture notes of “Human Ability” by Prof. James Landay, UCB

We still use the pinhole model …

- The model does not include geometric distortions or blurring of unfocused objects caused by lenses.
- Several of such effects can be compensated by additional procedures.
- It is a good approximation of mapping a 3D scene to a 2D image.