Distributed Ray Tracing

D.A. Forsyth, using John Hart's slides

Ray traced images look fake

- Jagged edges
- Hard shadows
- Everything in focus
- Objects completely still
- Surfaces perfectly shiny
- Glass perfectly clear

Randomized estimates of integrals

if $\quad x_i \sim p(x)$

then $\quad \frac{1}{N}\sum_{i=1}^{N} f(x_i) \rightarrow \int f(x)p(x)dx$

- i.e. we can approximate integrals with sums
  - example: p(x) uniform, stochastic sampling of pixel

Recall our image sensor model

- How do we get motion blur?
  - integrate over time

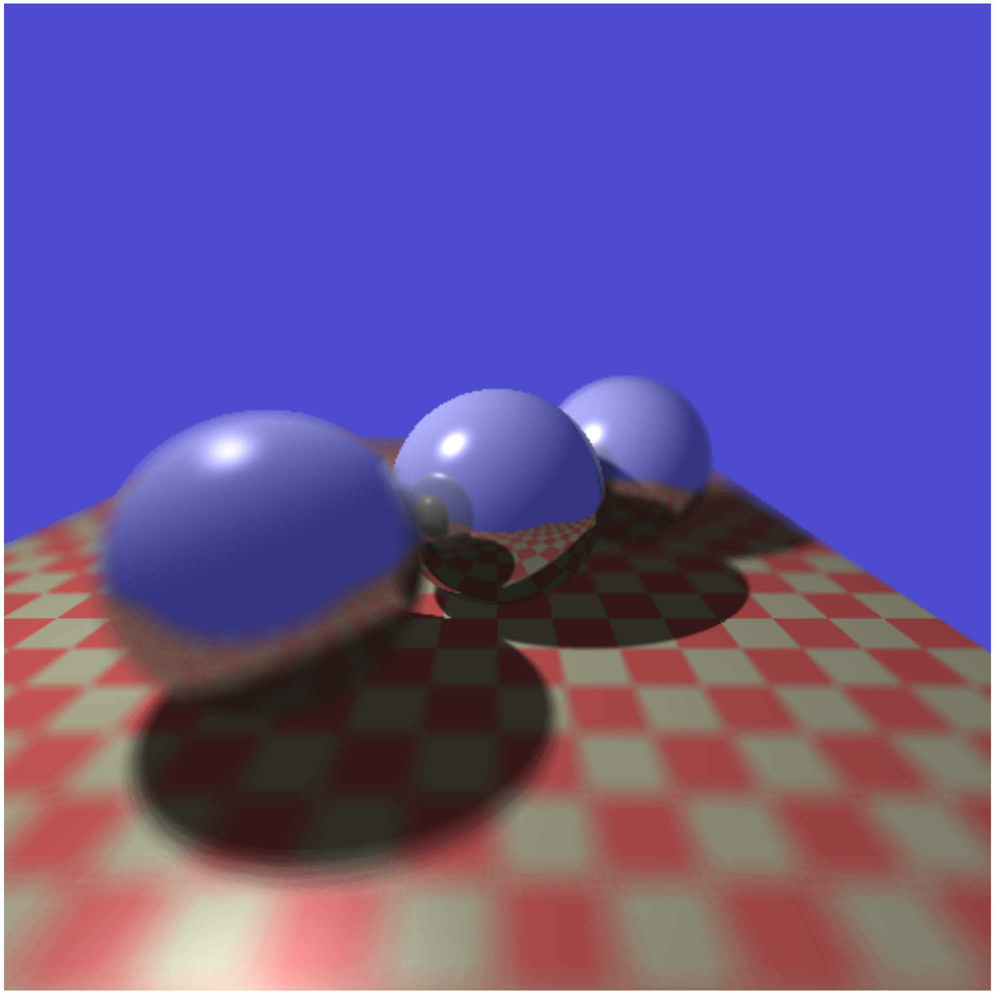
$$\text{value} = \int_A \int_\Omega \int_T I(x, y, \omega, t) w(x, y, \omega, t) dt d\omega dx dy$$

Motion Blur

- Multiple rays from eye through same point in each pixel
  - Each intersects the scene at a different time
  - Weight function (reconstruction filter) controls shutter speed, length
    - Box filter – fast shutter
    - Triangle filter – slow shutter

Depth of Field

- Better simulation of camera model
  - f-stop
  - focus

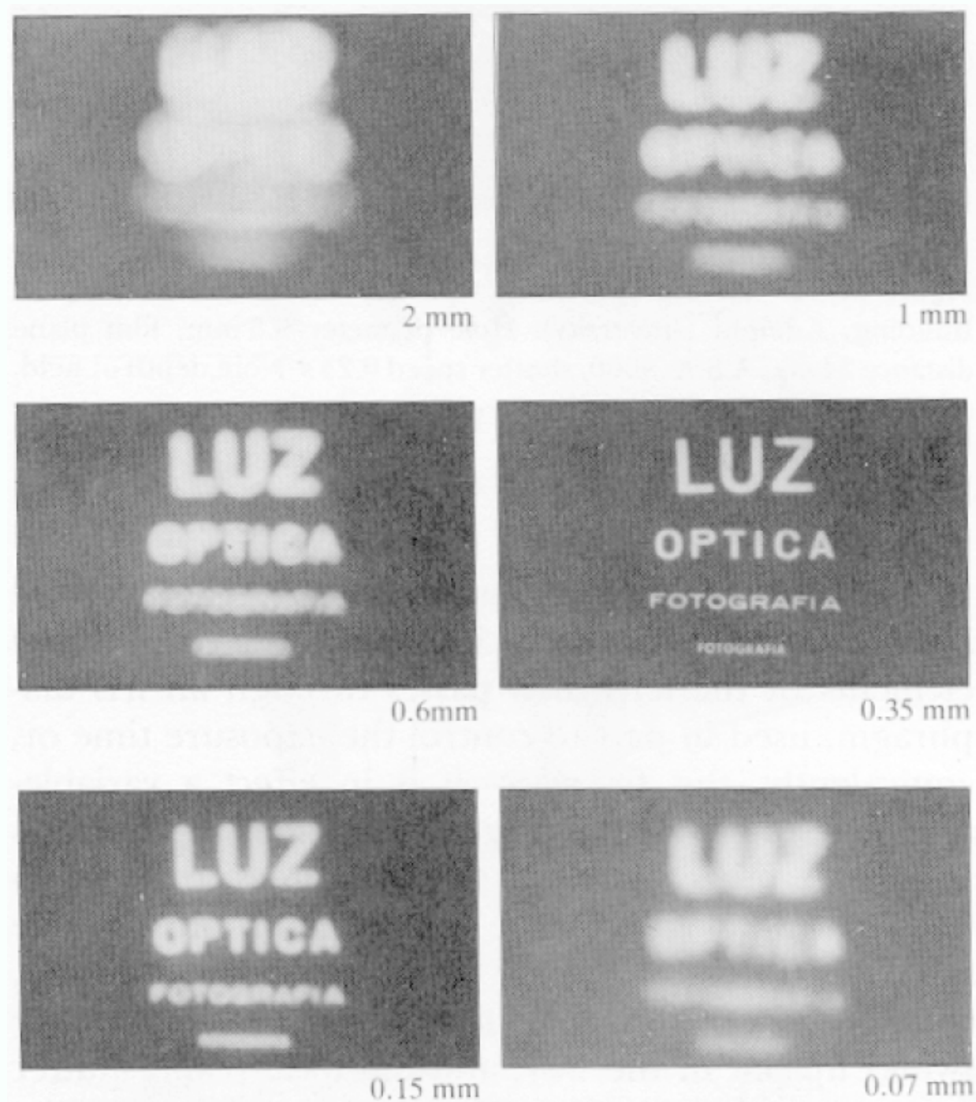


Pinhole Problems

Pinhole too big: brighter, but blurred

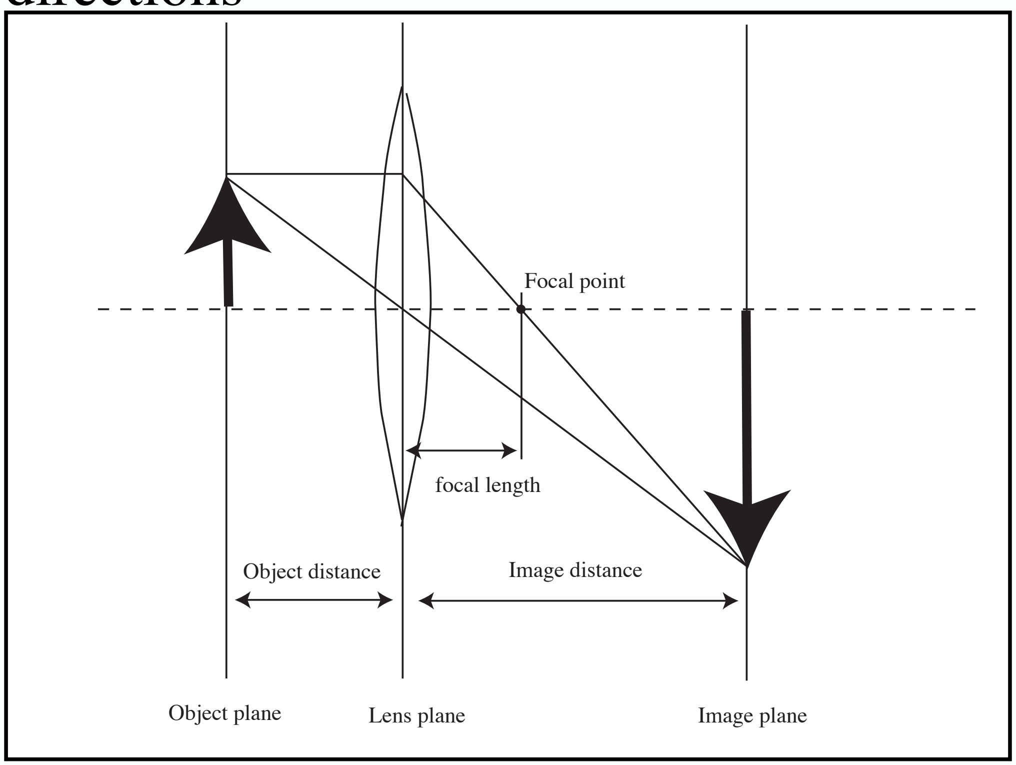
Pinhole right size: crisp, but dark

Pinhole too small: diffraction effects blur, dark



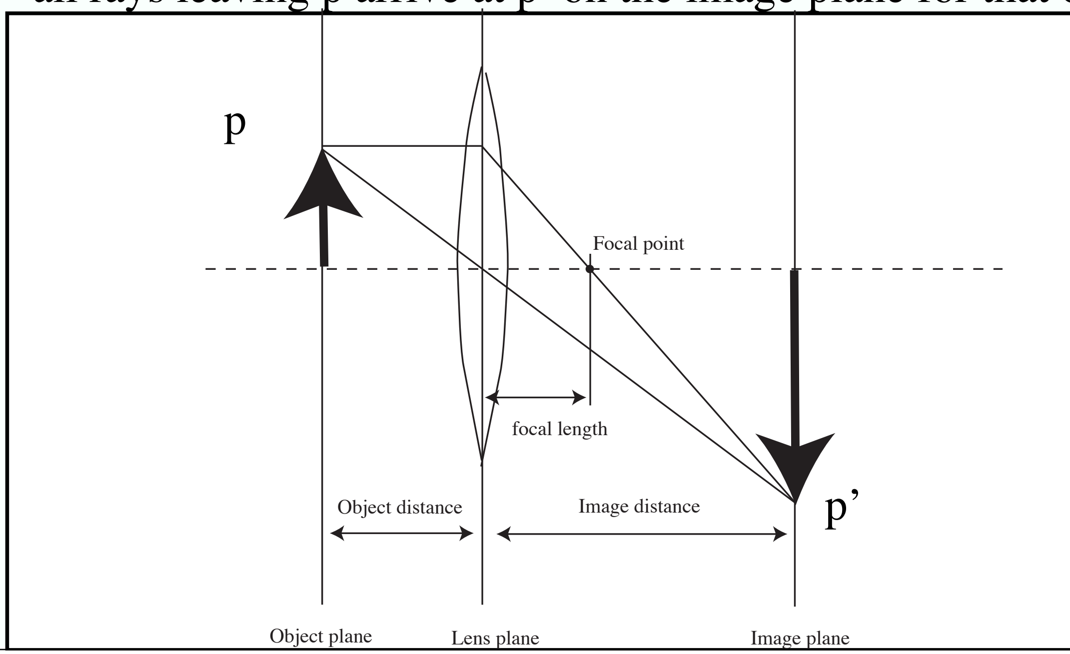
Thin lenses

- Thin circular pieces of refracting material
  - spherical in cross-section
  - circular, so we can use symmetry to draw, reason, etc.
- Make images brighter by collecting light from multiple directions



Thin lenses

- Rays parallel to axis pass through focal point
  - which is a property of the lens
  - Rays through center are not refracted
- Pairs object planes and image planes
- Any point p on an object yields an object plane
  - all rays leaving p arrive at p' on the image plane for that object plane



Thin lenses

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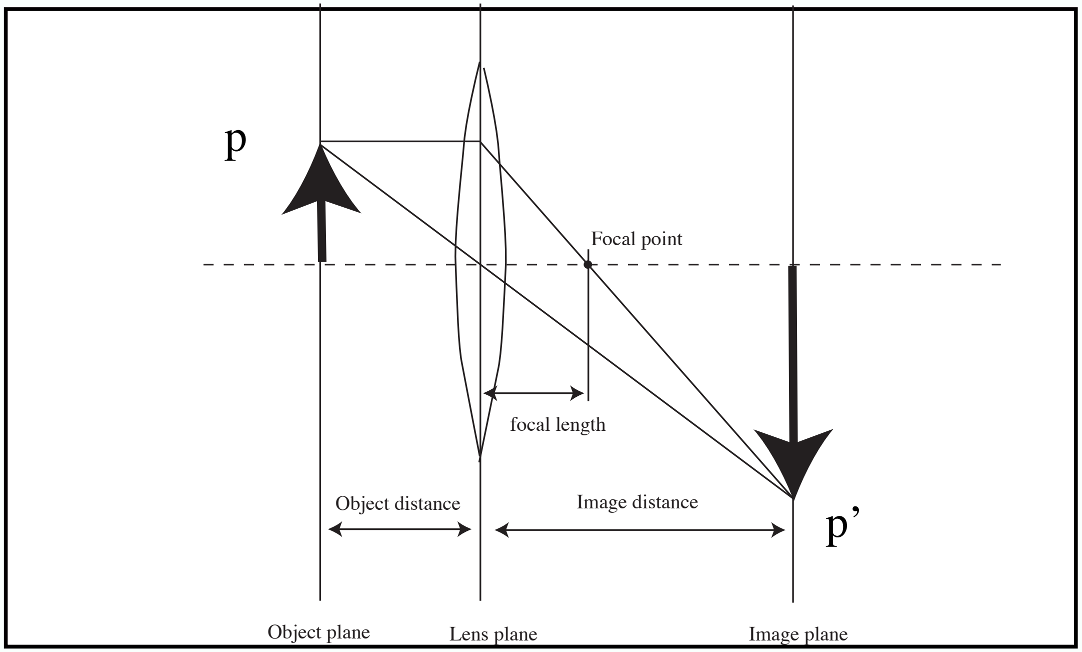
$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{\text{object distance}} + \frac{1}{\text{image distance}} = \frac{1}{\text{focal length}}$$



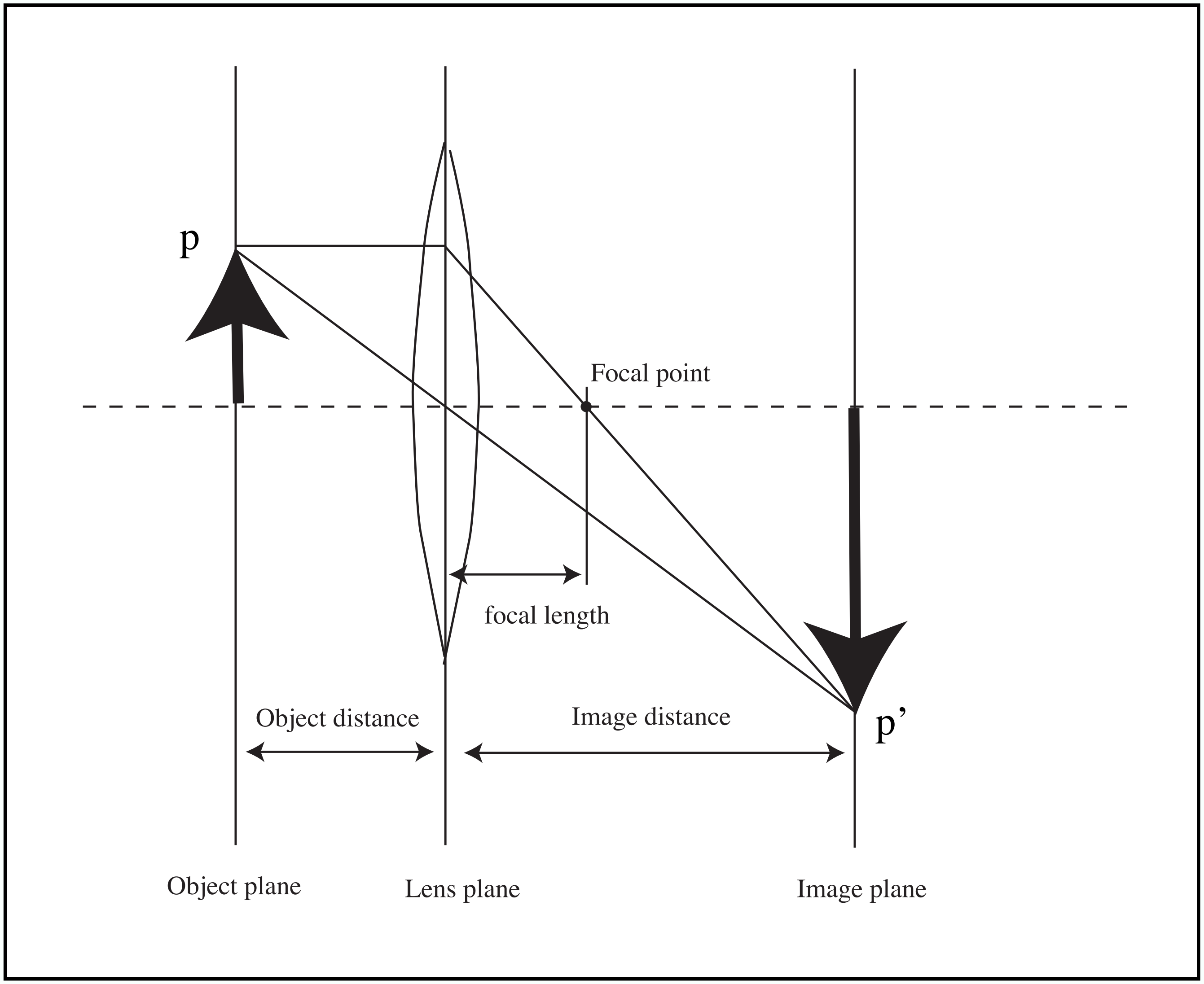
Thin lenses

- Thin lens equation
  - relates object distance, image distance, focal length
- Crucial, useful fact:
  - tells us where all rays arriving at a point on the image plane came from in space (we have a fixed image plane)

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{\text{object distance}} + \frac{1}{\text{image distance}} = \frac{1}{\text{focal length}}$$

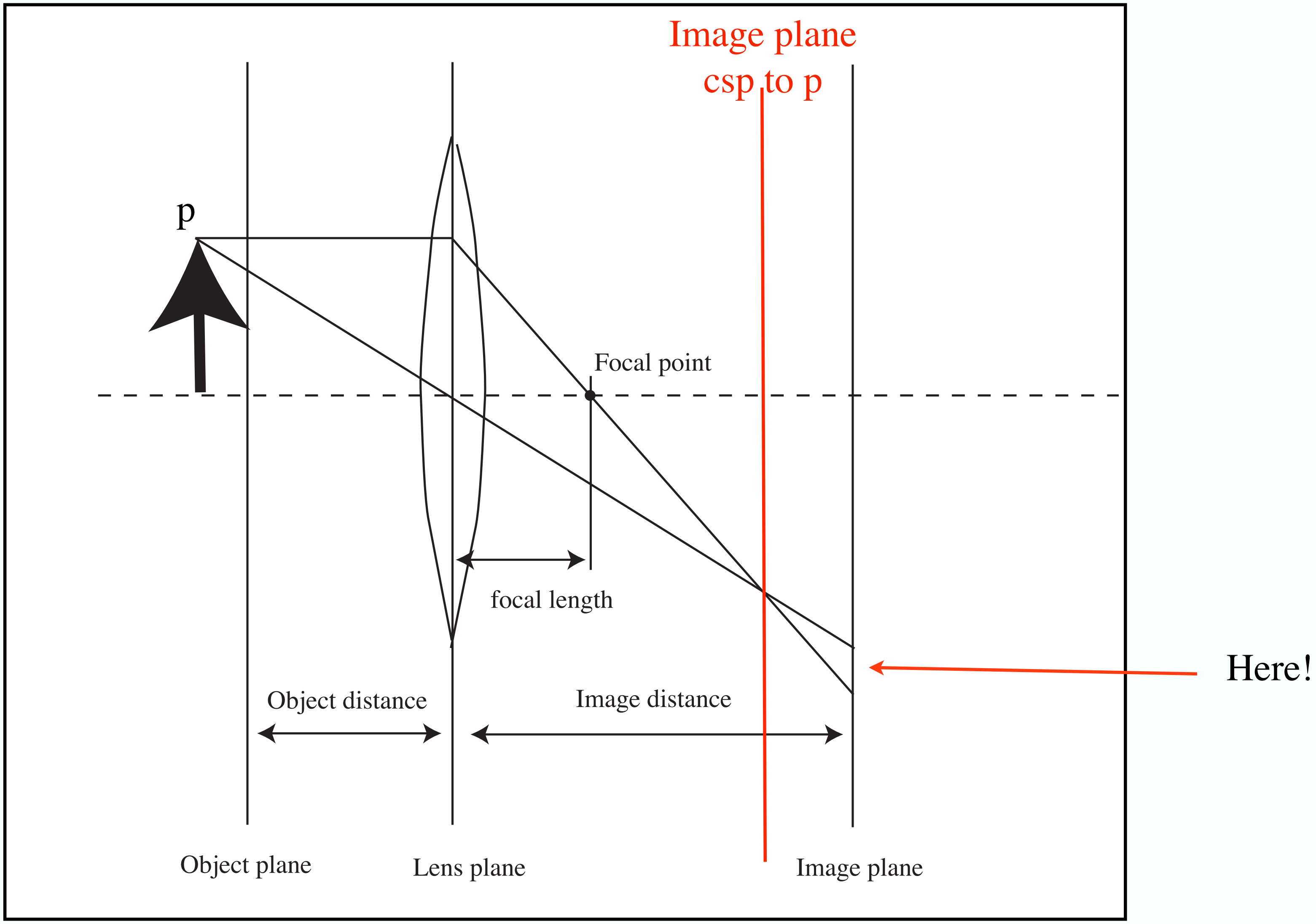
Thin Lenses


p
Focal point
focal length
Object distance
Image distance
p'
Object plane
Lens plane
Image plane

Thin lenses

- Yields
  - a model of aperture and defocus
    - because points not on the object plane given by our image plane become “blobs”
  - how to ray trace a thin lens
    - because we can tell where every ray arriving at p’ on our image plane came from

Circle of confusion



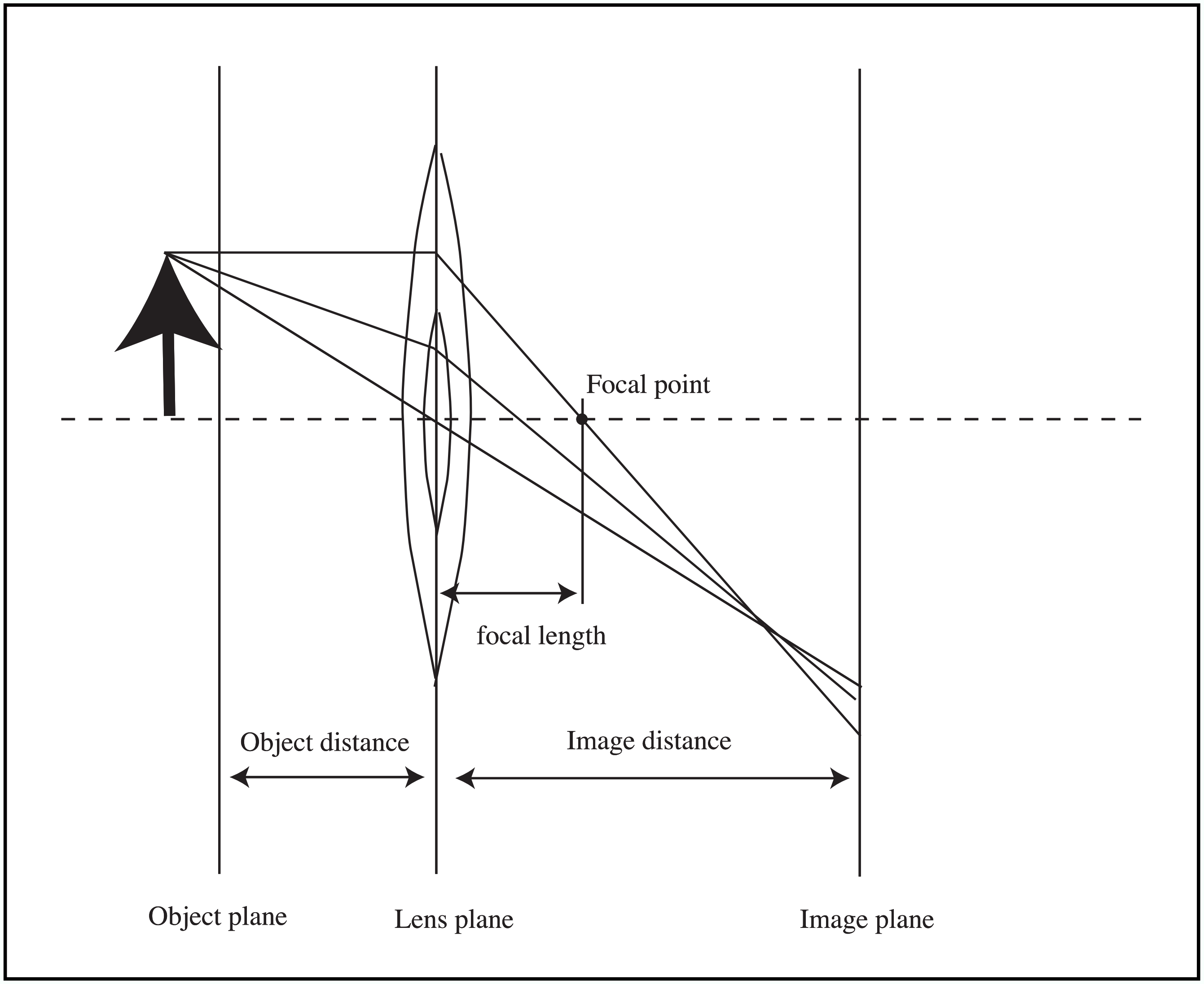
Computing depth of field of a lens

- Choose an acceptable circle of confusion size
  - this gives a range of depths around the object plane where objects will be in focus

Aperture

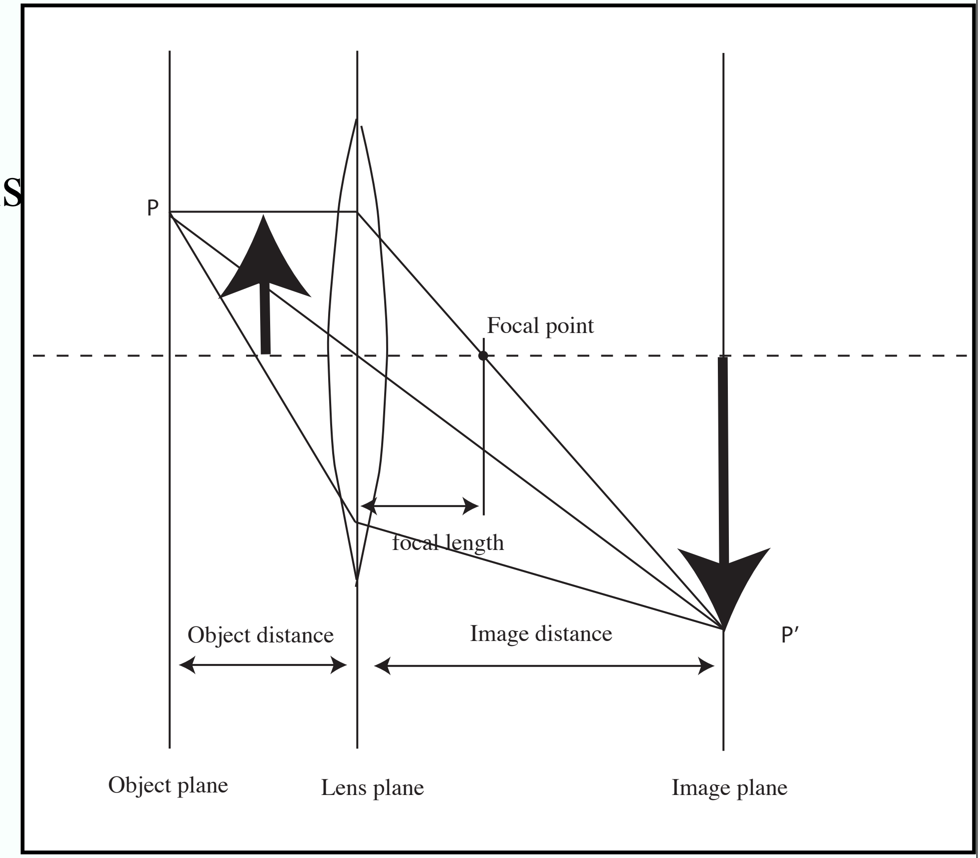
- The size of the “opening” represented by the lens
  - height of lens in drawing
- Smaller aperture -> bigger depth of field, darker
  - smallest=pinhole=infinite depth of field
  - but it’s dark
- Larger aperture -> more light, smaller depth of field

Aperture


Focal point
focal length
Object distance
Image distance
Object plane
Lens plane
Image plane

Rendering

- At each pixel, fire rays in randomly chosen directions toward the lens
  - average (this average is an integral!)
  - where do these rays go?
  - use thin lens equation!
  - effects
    - depth of field (or defocus)
    - aperture



Advanced camera models

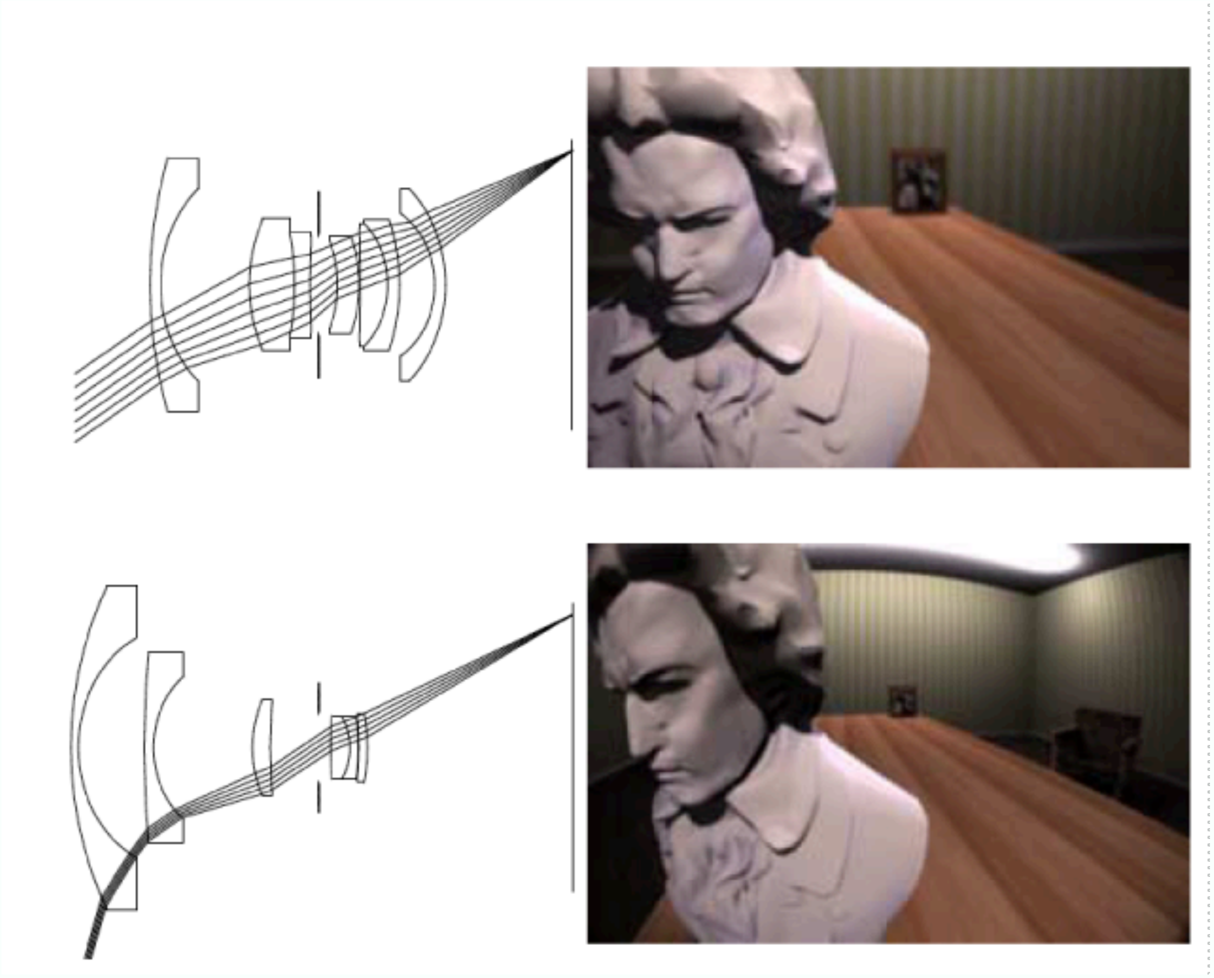


figure from Kolb, Mitchell and Hanrahan, 1995

Advanced lens systems