CS130 : Computer Graphics
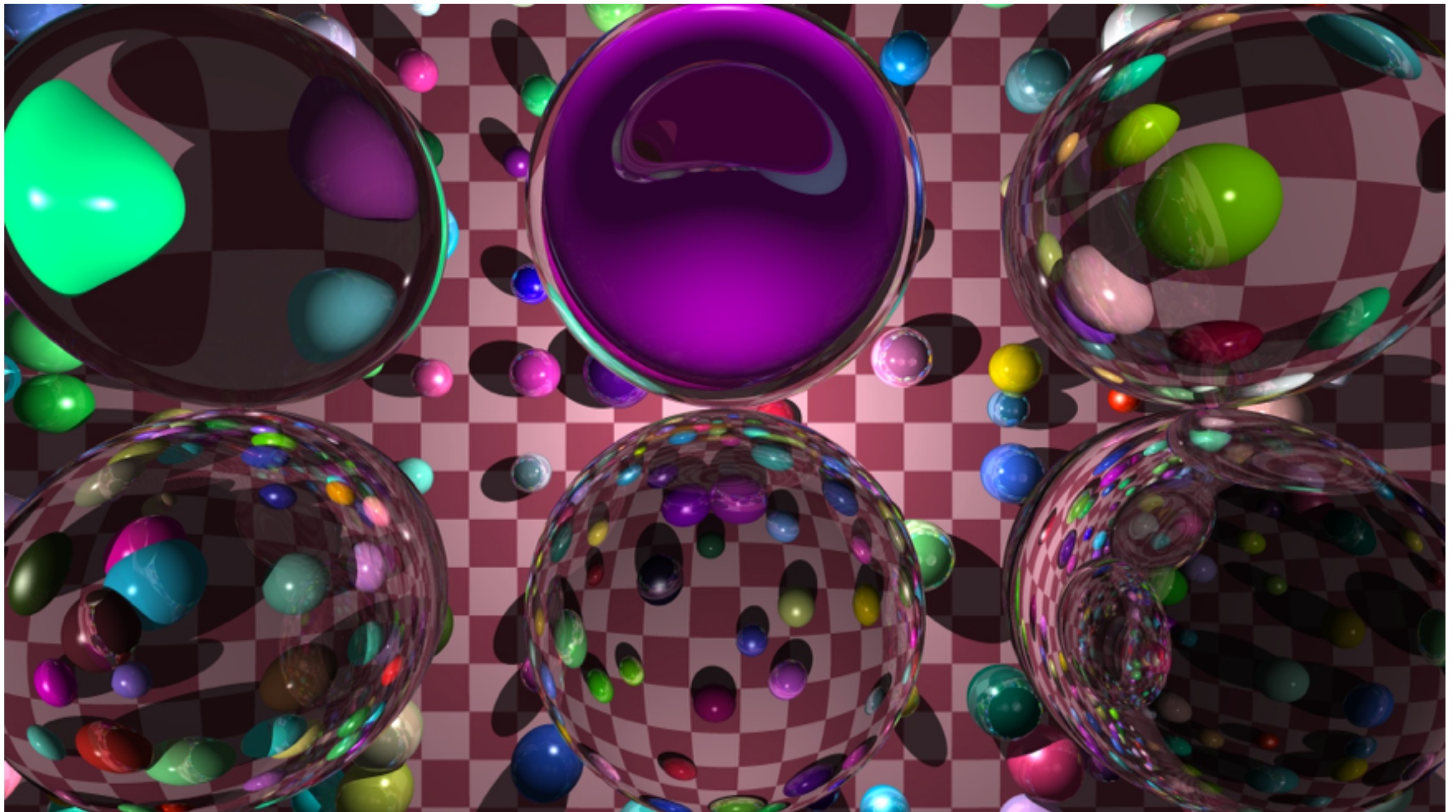## Ray Tracing (cont.)

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ray tracer extensions

- refraction
- more complex geometry
  - instancing
  - CSG
- distribution ray tracing (Cook et al., 1984)
  - antialiasing
  - soft shadows
  - depth of field
  - fuzzy reflections
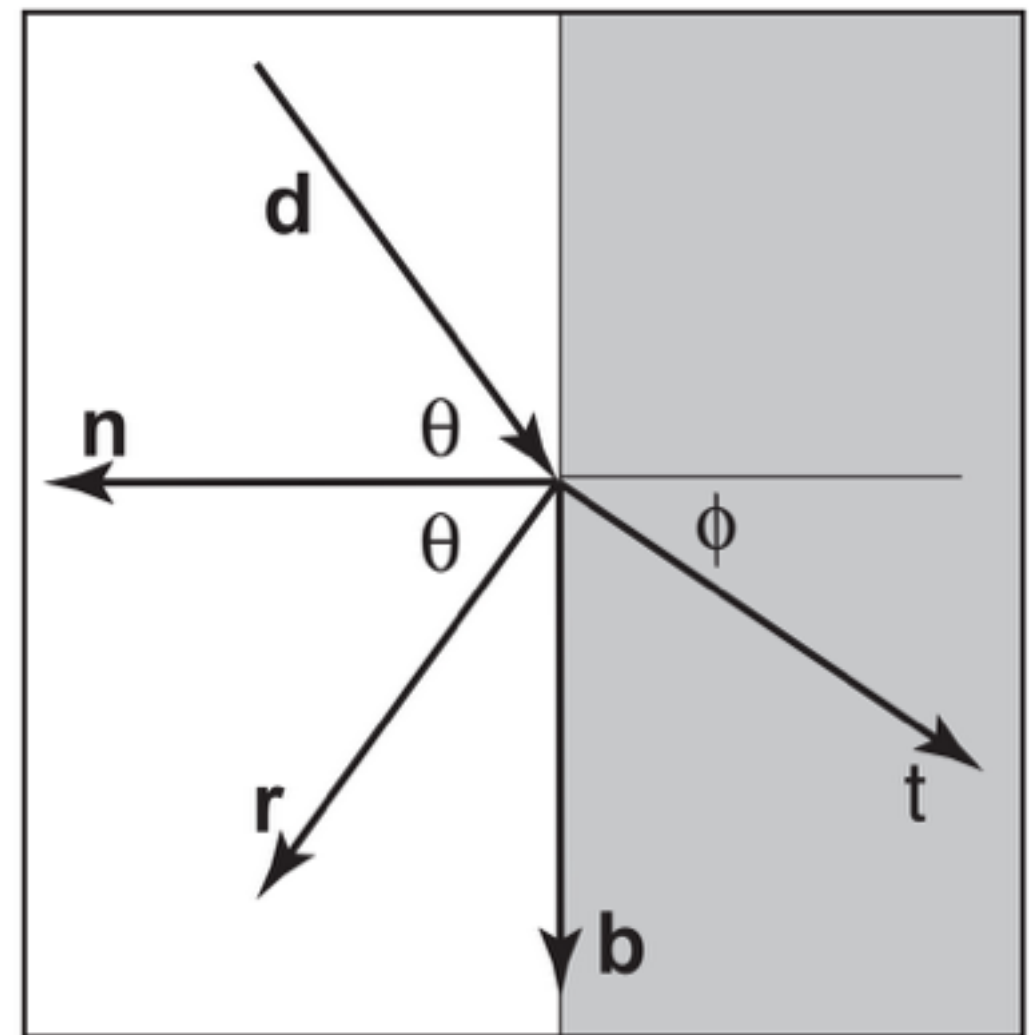 - motion blur

Transparency and Refraction

Transparency and Refraction

Snell's Law

n1 sinθ= n2 sinφ

Example values of *n*:
air: 1.00;
water: 1.33–1.34;
window glass: 1.51;
optical glass: 1.49–1.92;
diamond: 2.42.

<whiteboard>
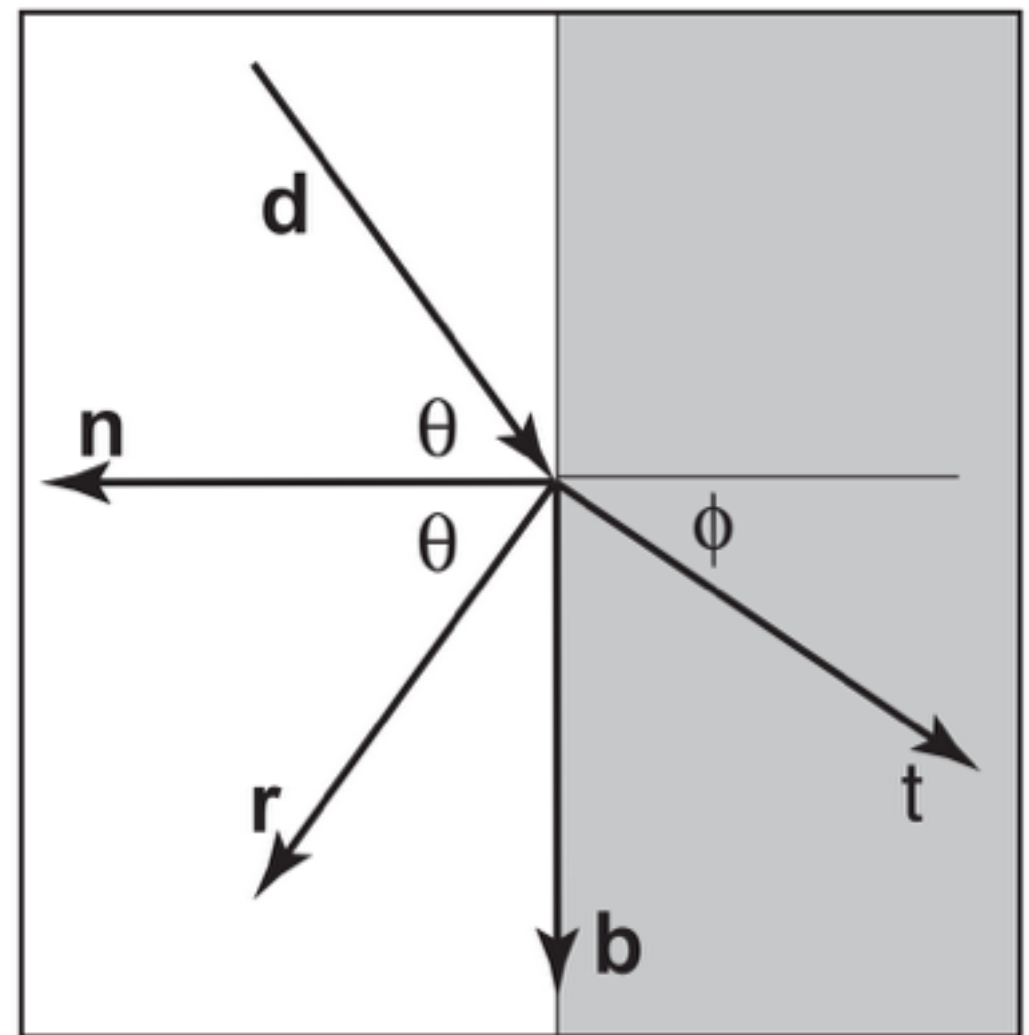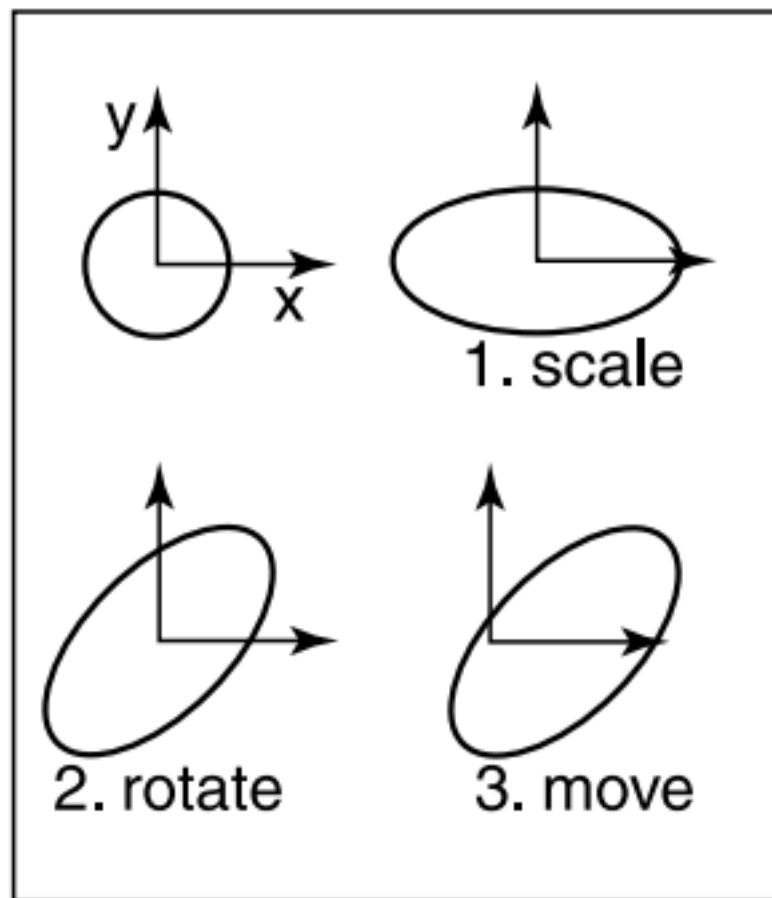
Transparency and Refraction

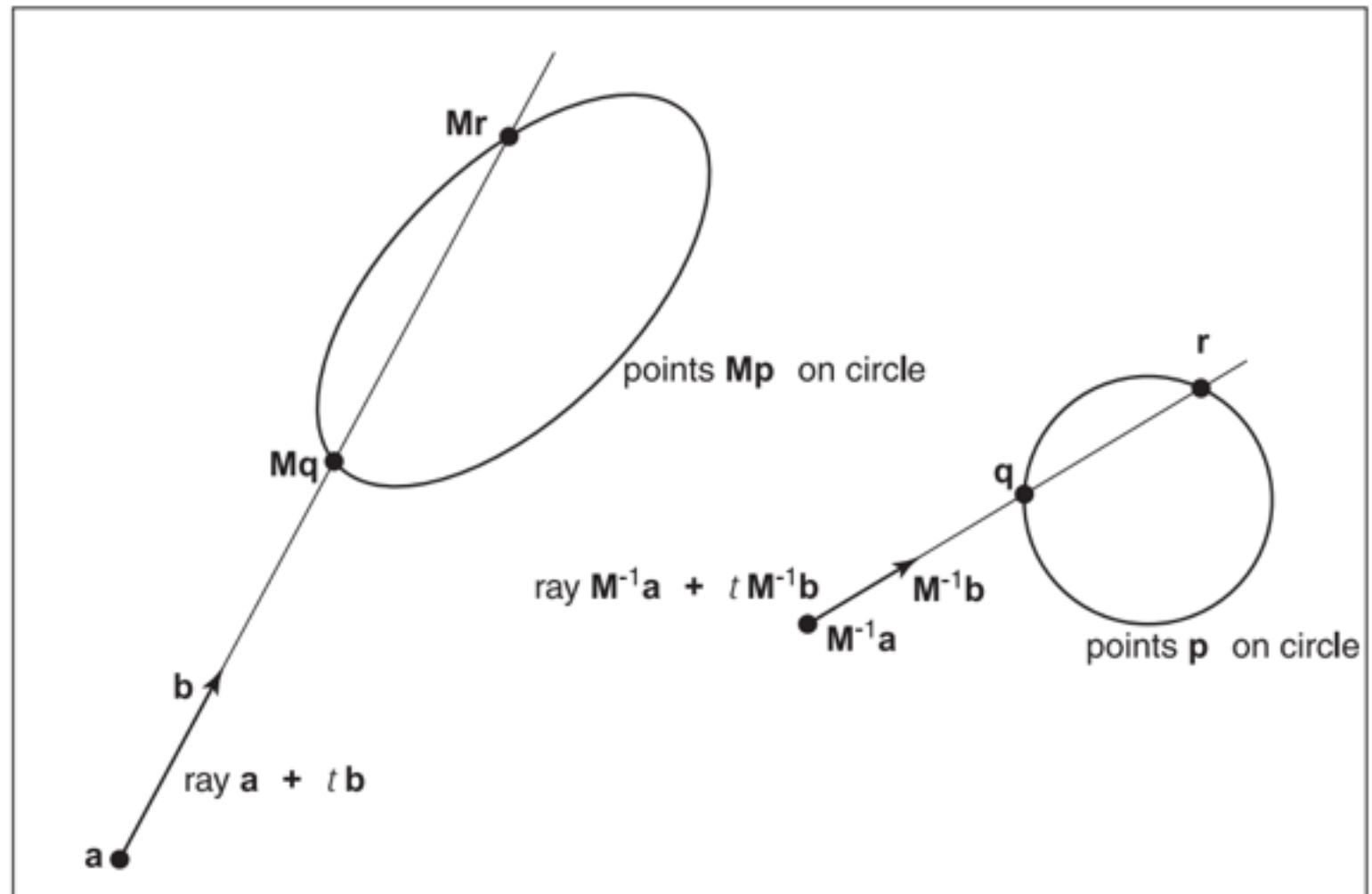Snell's Law

Additional effects
- varying reflectivity
  Fresnel equations
- attenuation of light intensity
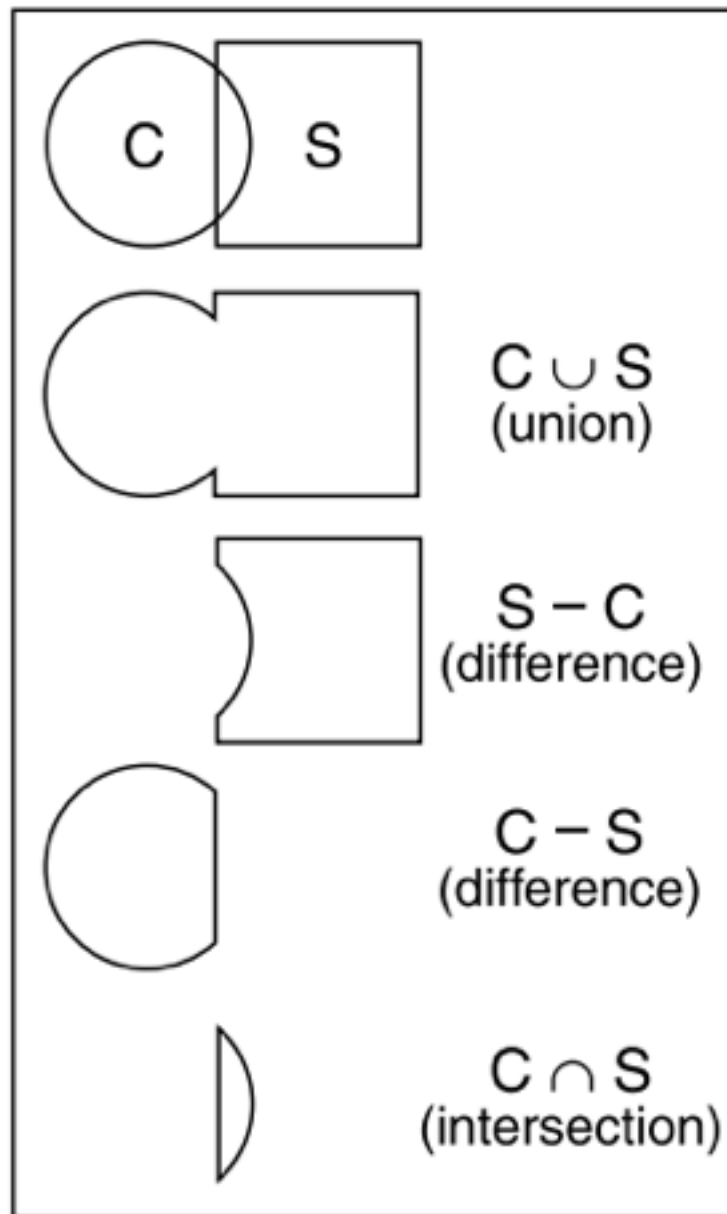 *Beer's Law*

Object Instancing

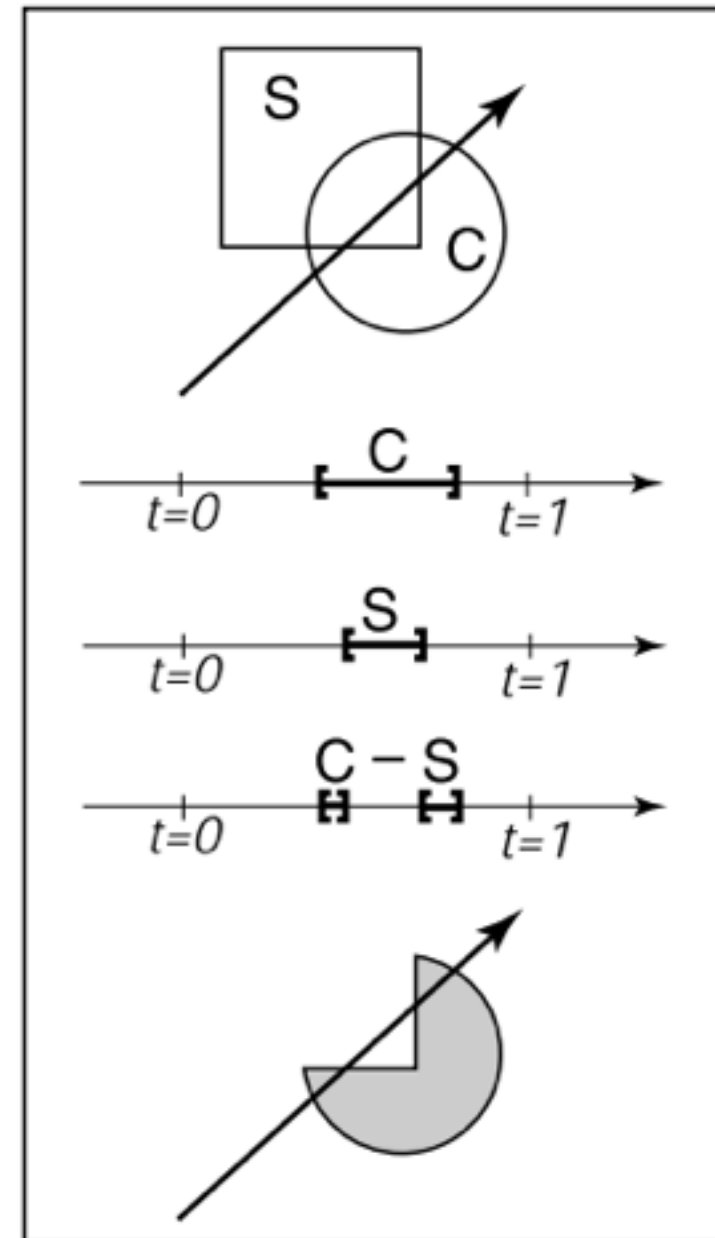

instance of circle with 3
transformations applied

ray intersection problem in the
two spaces are simple
transforms of each other

Constructive Solid Geometry (CSG)

$C \cup S$
(union)

$S - C$
(difference)

$C - S$
(difference)

$C \cap S$
(intersection)

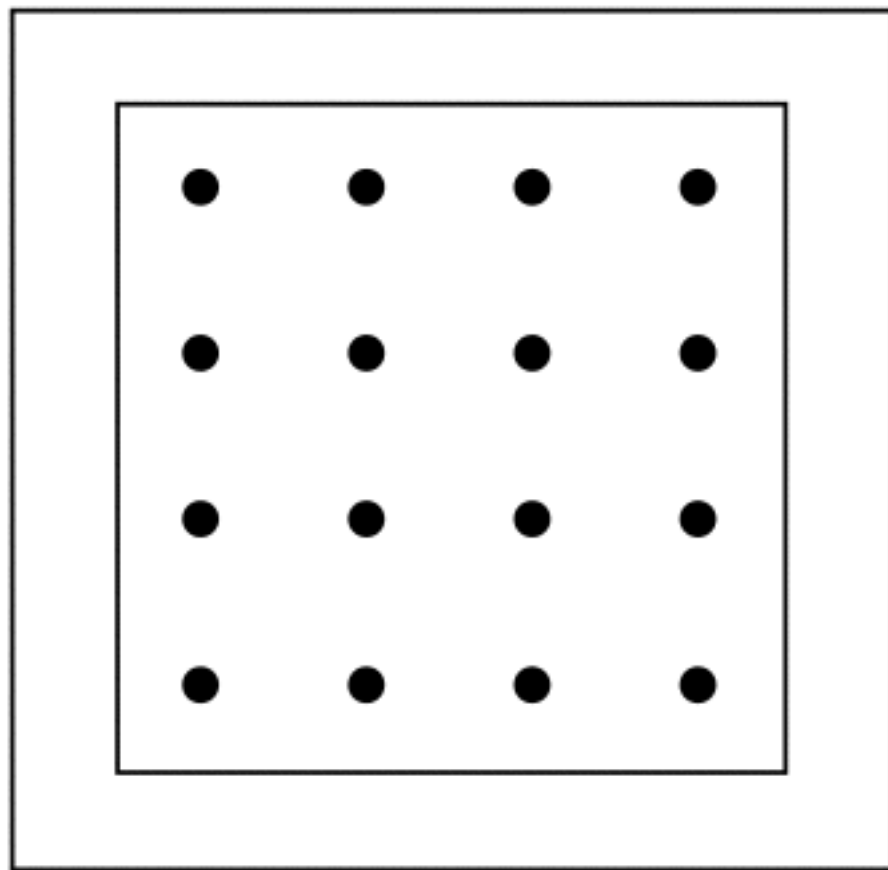use set operations to
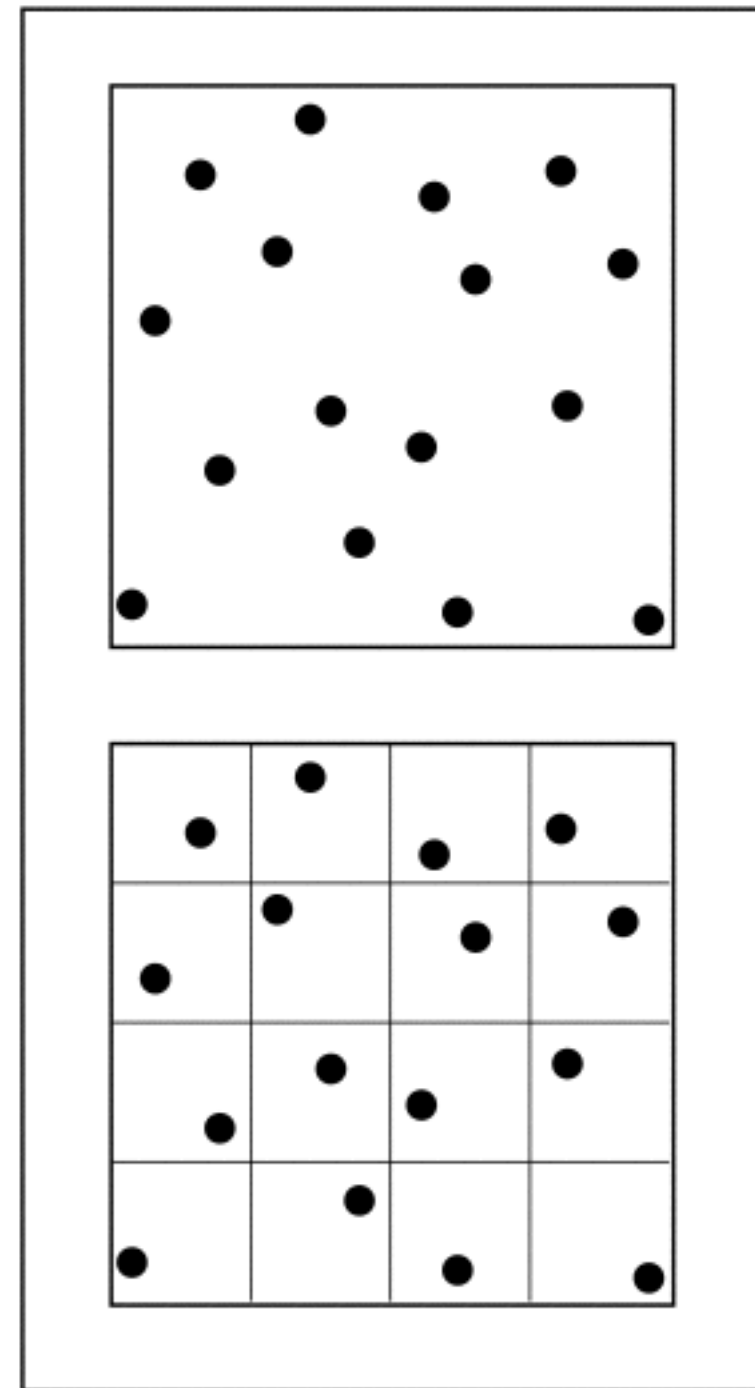combine solid shapes

intersection with
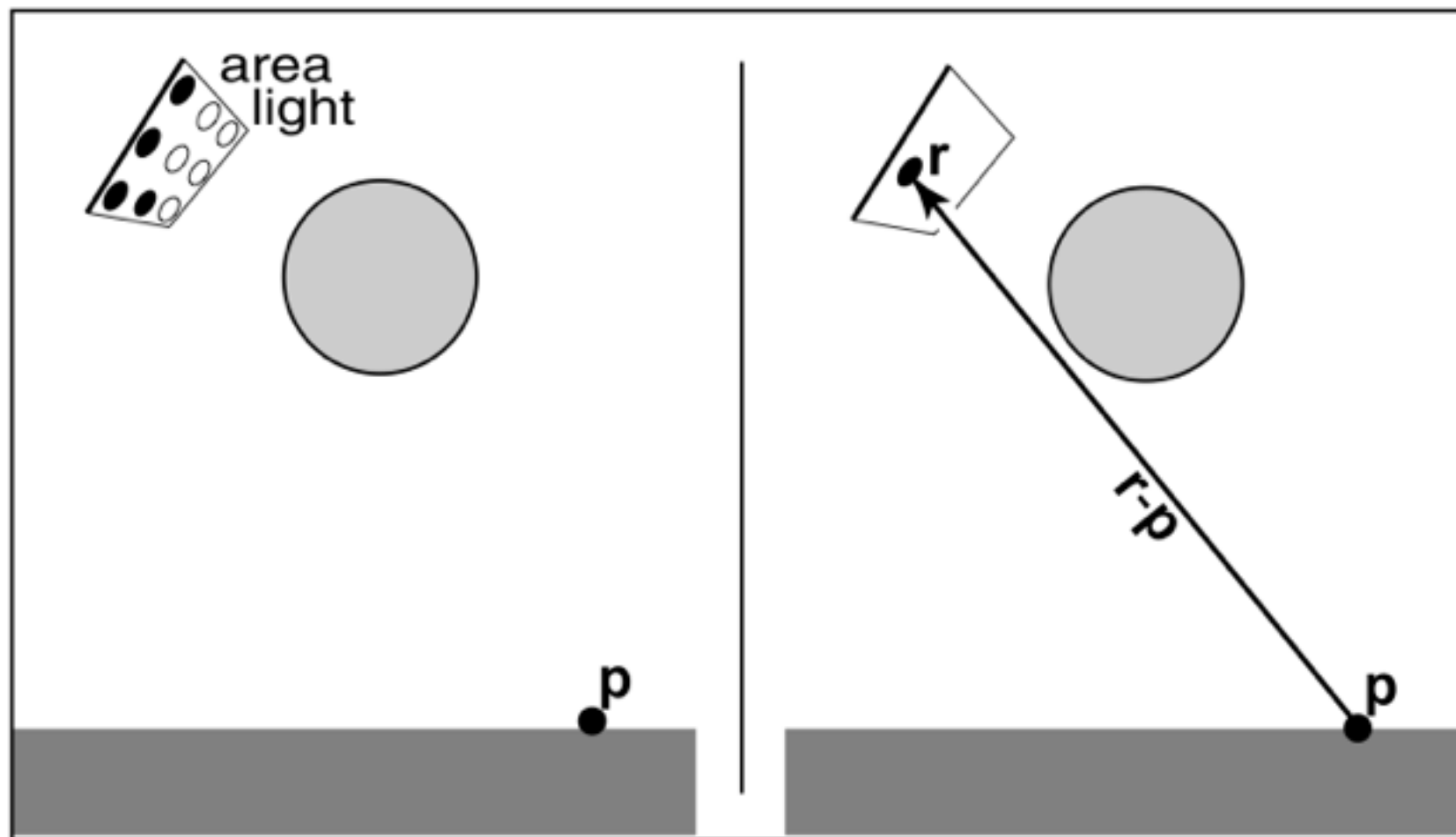composite object

Distribution Ray Tracing

Anti-aliasing

16 regular samples / pixel

jittered samples

[Shirley and Marschner]
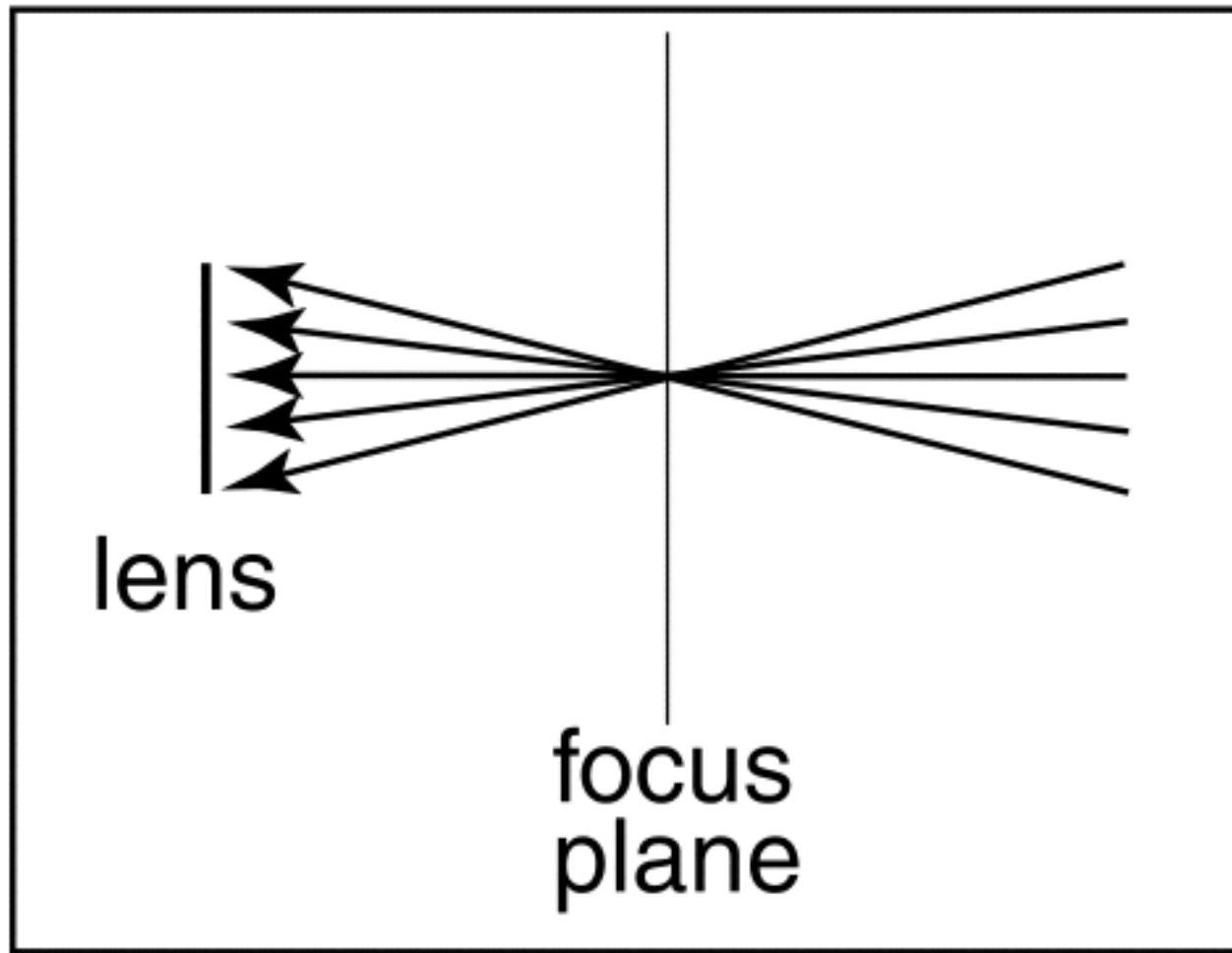
Soft Shadows

$$\mathbf{r} = \mathbf{c} + \xi_1\mathbf{a} + \xi_2\mathbf{b}.$$
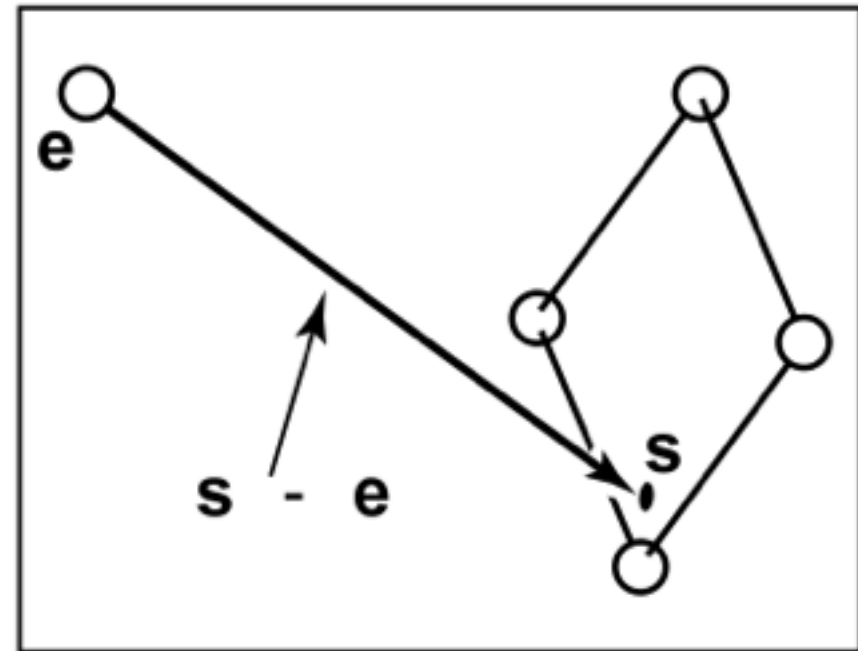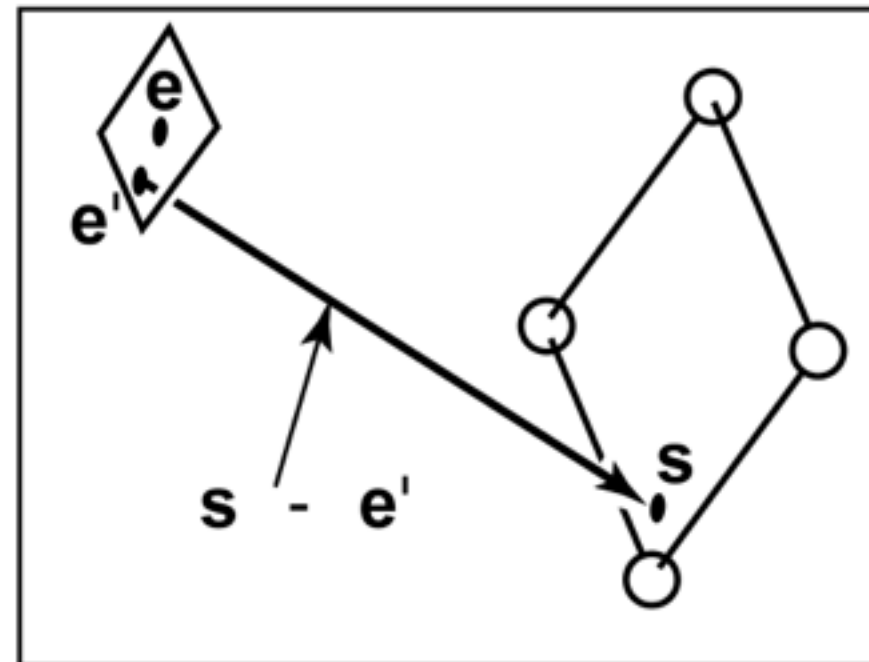
Soft Focus (depth of field)

lens (eye location) averages
over a cone of directions

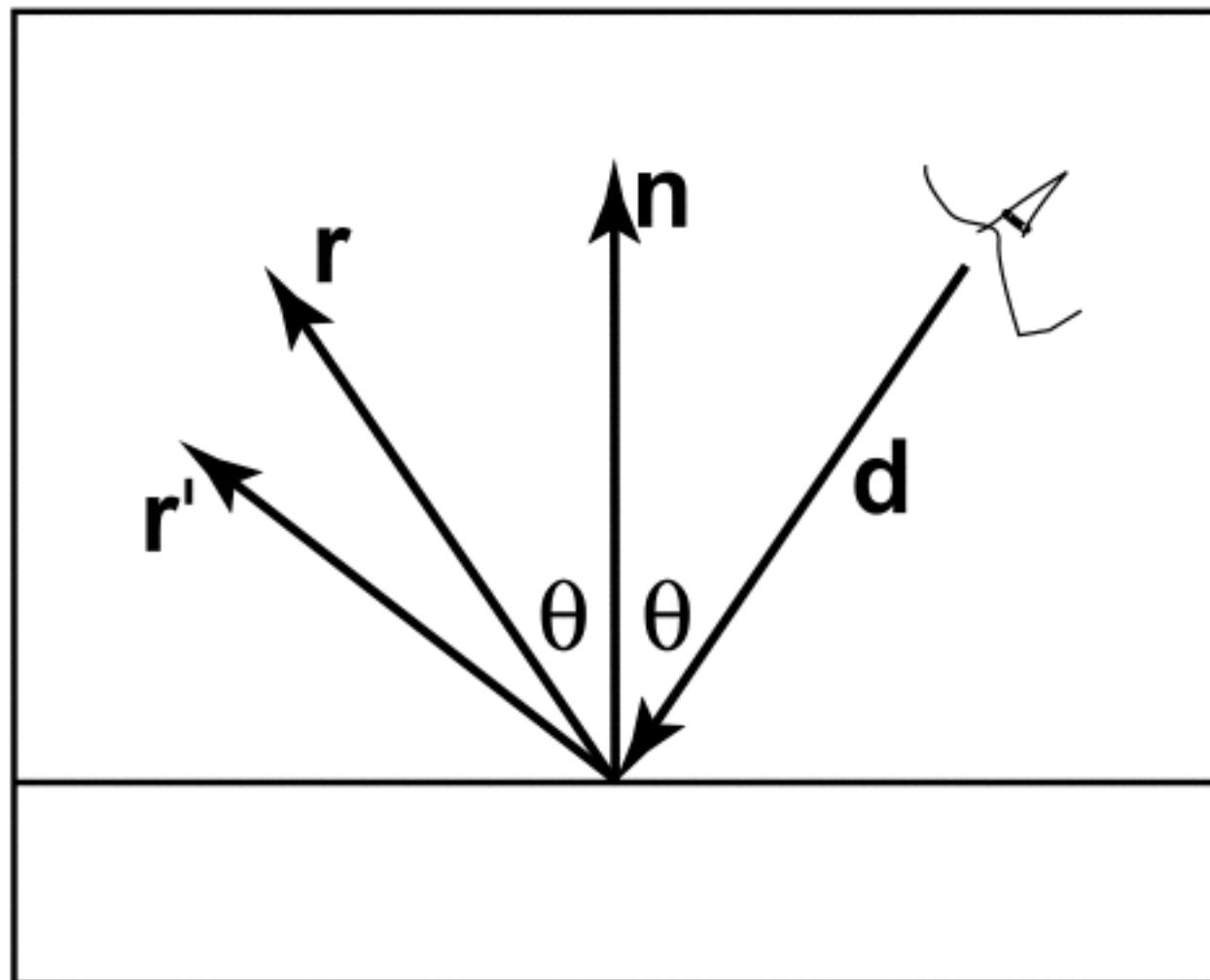without depth of field

with depth of field

[Shirley and Marschner]

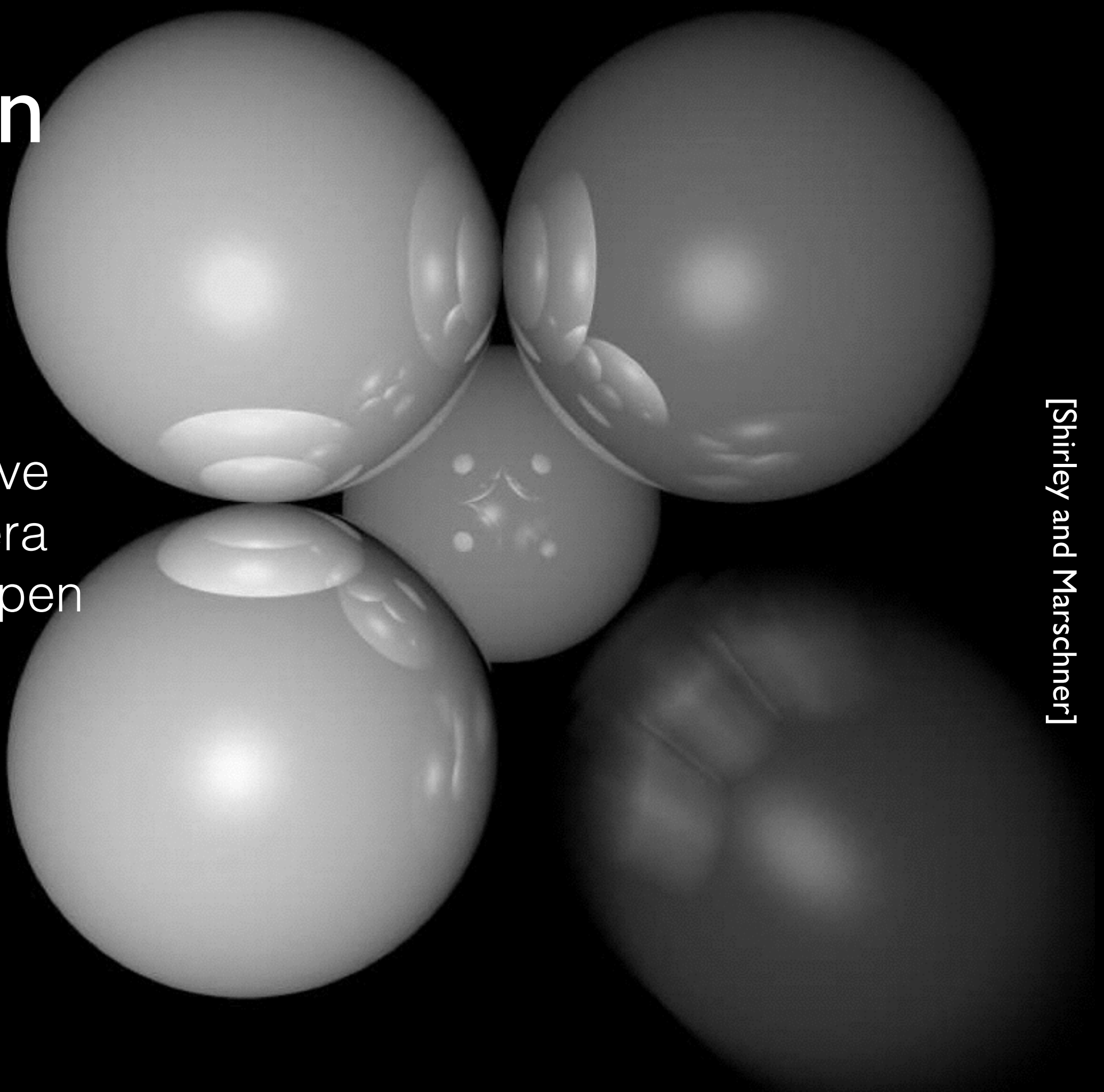image using 25 samples per pixel

Fuzzy Reflections

randomly perturb ideal
specular reflection rays

Motion Blur

objects move
while camera
aperture is open

[Shirley and Marschner]

Motion Blur

to simulate, choose random time within open aperture interval for each view ray

[Shirley and Marschner]