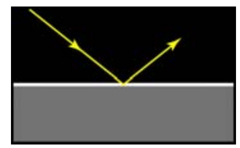
Lighting II

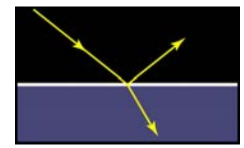
CS 465 Lecture 19

Specular reflection

- Smooth surfaces of pure materials have ideal specular reflection (said this before)
  - Metals (conductors) and dielectrics (insulators) behave differently
- Reflectance (fraction of light reflected) depends on angle

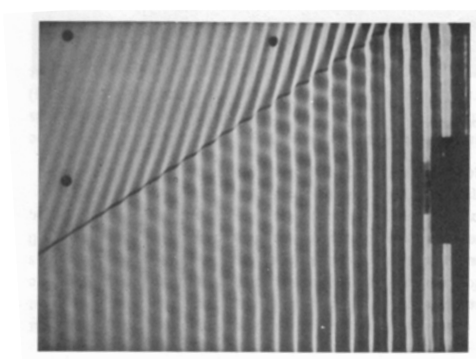


metal



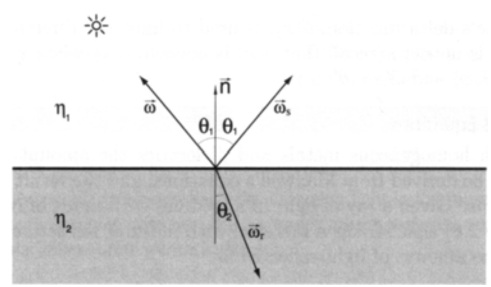
dielectric

Refraction at boundary of media



Snell's Law

- Tells us where the refracted ray goes



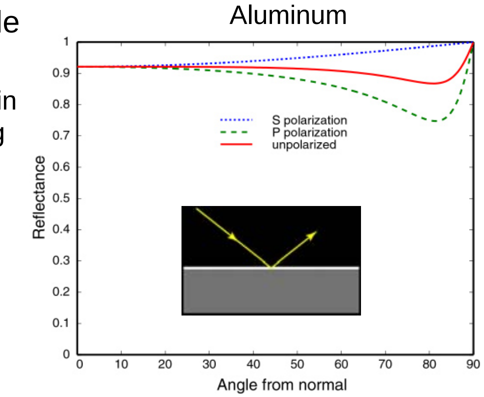
$$\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$$

Ray tracing dielectrics

- Like a simple mirror surface, use recursive ray tracing
- But we need two rays
  - One reflects off the surface (same as mirror ray)
  - The other crosses the surface (computed using Snell's law)
    - Doesn't always exist (total internal reflection)
- Splitting into two rays, recursively, creates a ray tree
  - Very many rays are traced per viewing ray
  - Ways to prune the tree
    - Limit on ray depth
    - Limit on ray attenuation

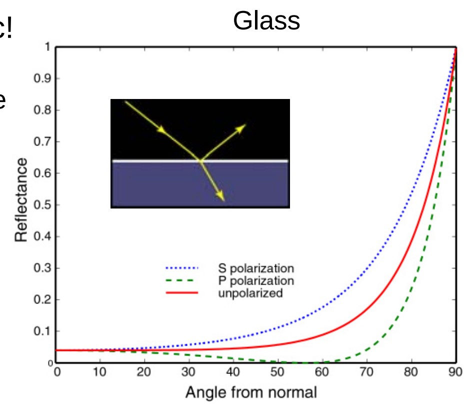
Specular reflection from metal

- Reflectance does depend on angle
  - but not much
  - safely ignored in basic rendering



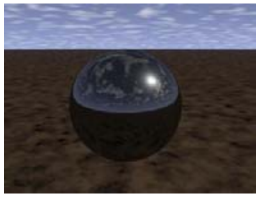
Specular reflection from glass/water

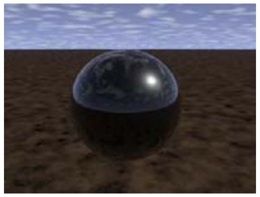
- Dependence on angle is dramatic!
  - about 4% at normal incidence
  - always 100% at grazing
  - remaining light is transmitted
- This is important for proper appearance



Fresnel reflection

- Black glazed sphere
  - reflection from glass surface
  - transmitted ray is discarded


constant reflectance


Fresnel reflectance

Fresnel’s formulas

- They predict how much light reflects from a smooth interface between two materials
  - usually one material is empty space

$$F_p = \frac{\eta_2 \cos\theta_1 - \eta_1 \cos\theta_2}{\eta_2 \cos\theta_1 + \eta_1 \cos\theta_2}$$

$$F_s = \frac{\eta_1 \cos\theta_1 - \eta_2 \cos\theta_2}{\eta_1 \cos\theta_1 + \eta_2 \cos\theta_2}$$

$$R = \frac{1}{2}\left(F_p^2 + F_s^2\right)$$

  - R is the fraction that is reflected
  - $(1 - R)$ is the fraction that is transmitted

Schlick’s approximation

- For graphics, a quick hack to get close with less computation:

$$\tilde{R} = R_0 + (1 - R_0)(1 - \cos\theta)^5$$

- R_0 is easy to compute:

$$F_p = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$F_s = \frac{\eta_1 - \eta_2}{\eta_1 + \eta_2}$$

$$R_0 = \left(\frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}\right)^2$$

[Josh Wills | 2003 UCSD Rendering Competition]

Fresnel reflection

[Mike Hill & Gaain Kwan | Stanford cs348 competition 2001]

Basic ray tracing

- Many advanced methods build on the basic ray tracing paradigm
- Basic ray tracer: one sample for everything
  - one ray per pixel
  - one shadow ray for every point light
  - one reflection ray, possibly one refraction ray, per intersection

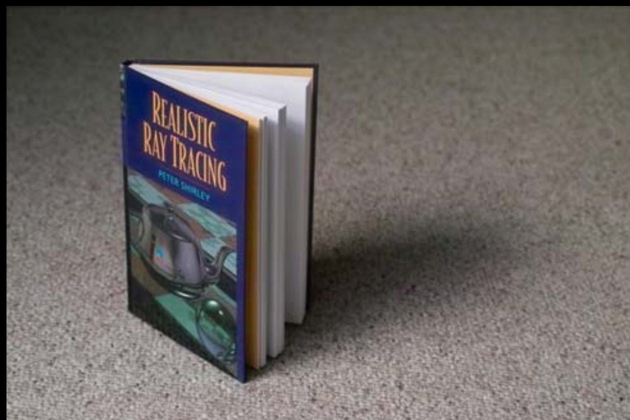
Discontinuities in basic RT

- Perfectly sharp object silhouettes in image
  - leads to aliasing problems (stair steps)
- Perfectly sharp shadow edges
  - everything looks like it's in direct sun
- Perfectly clear mirror reflections
  - reflective surfaces are all highly polished
- Perfect focus at all distances
  - camera always has an infinitely tiny aperture
- Perfectly frozen instant in time (in animation)
  - motion is frozen as if by strobe light

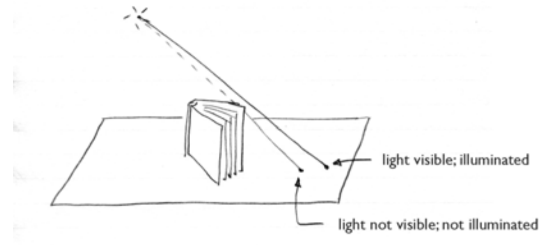
Basic ray traced image

[Glassner 89]

Soft shadows

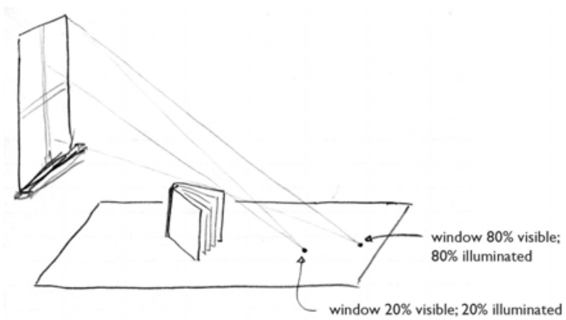


Cause of soft shadows



point lights cast hard shadows

Cause of soft shadows

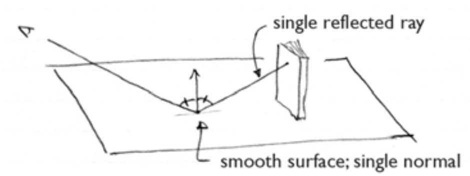


area lights cast soft shadows

Glossy reflection

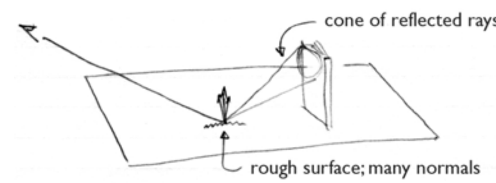
[Lafortune et al. 97]

Cause of glossy reflection



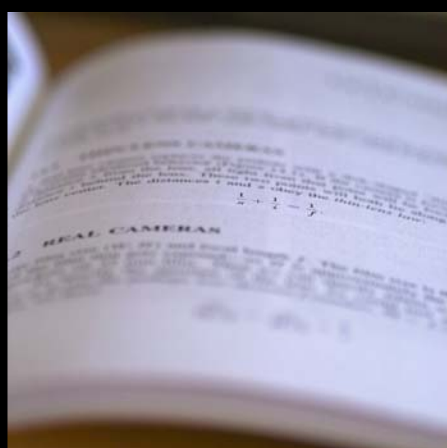
smooth surfaces produce sharp reflections

Cause of glossy reflection

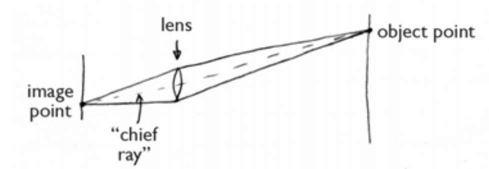


rough surfaces produce soft (glossy) reflections

Depth of field

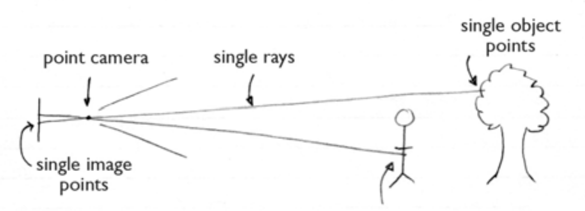


Cause of focusing effects



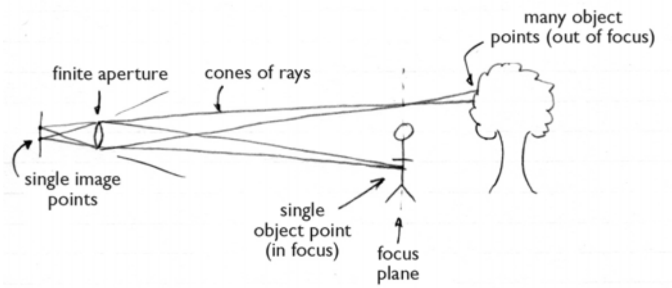
what lenses do (roughly)

Cause of focusing effects



point aperture produces always-sharp focus

Cause of focusing effects

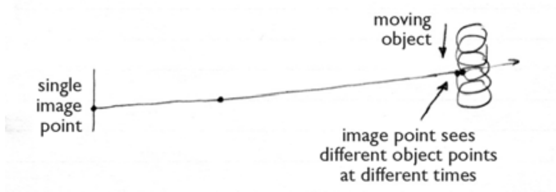


finite aperture produces limited depth of field

Motion blur

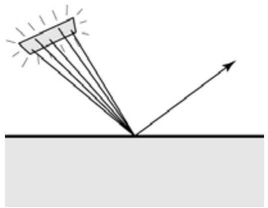
[Cook, Porter, Carpenter 1984]

Cause of motion blur



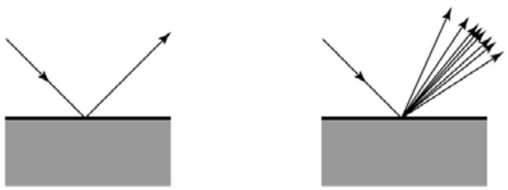
Creating soft shadows

- For area lights: use many shadow rays
  - and each shadow ray gets a different point on the light
- Choosing samples
  - general principle: start with uniform in square



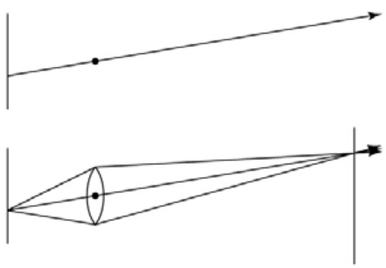
Creating glossy reflections

- Jitter the reflected rays
  - Not exactly in mirror direction; add a random offset
  - Can work out math to match Phong exactly
  - Can do this by jittering the normal if you want



Depth of field

- Make eye rays start at random points on aperture
  - always going toward a point on the focus plane



Motion blur

- Caused by finite shutter times
  - strobing without blur
- Introduce time as a variable throughout the system
  - object are hit by rays according to their position at a given time
- Then generate rays with times distributed over shutter interval

Generating samples

- A complicated question in general
- Basic idea: start with random points in a square
- Monte Carlo methods—CS 667