CS 563 Advanced Topics in Computer Graphics
Realistic Transparency

by Nik Deapen

Topics

- Fresnel Equations
- Color Filtering
- Implementation
- Some Topics
- Photon Mapping and Caustics

Fresnel Equations

- In Chapter 27 kr and kt were constant
  - now they depend on the incidence angle and the relative dielectric constants

$$r_{||} = \frac{\eta\ \cos\theta_i - \cos\theta_t}{\eta\ \cos\theta_i - \cos\theta_t}$$

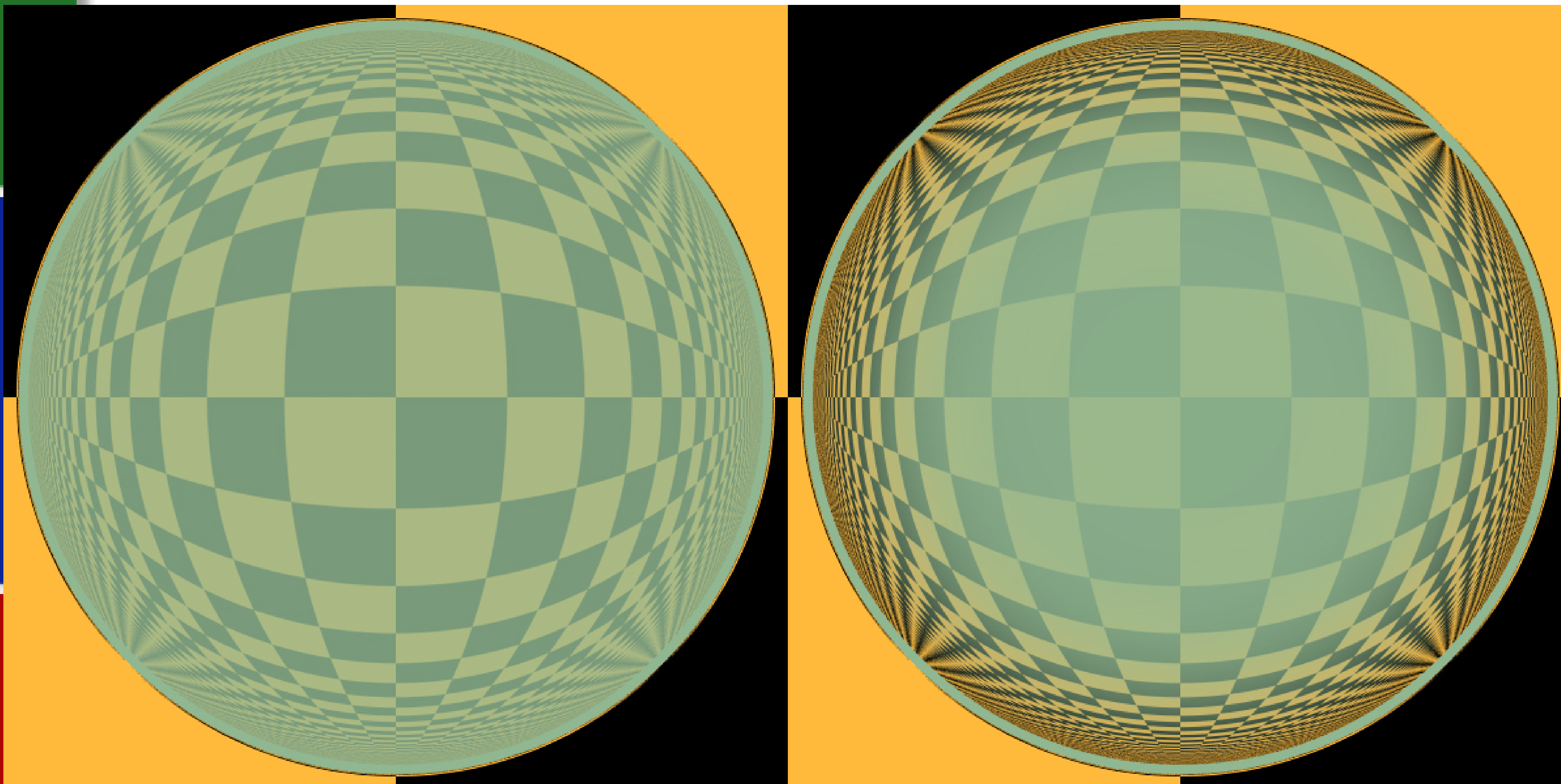
$$r_{\perp} = \frac{\cos\theta_i - \eta\cos\theta_t}{\cos\theta_i - \eta\cos\theta_t}$$

$$\eta = \frac{\eta_{in}}{\eta_{out}}$$

$$k_r = \frac{{r_{||}}^2 + {r_{\perp}}^2}{2}$$

$$k_t = 1 - k_r$$

Simple vs Dielectric (Fisheye)



Special Cases

- When you shoot from the direction of the normal (Normal Incidence)

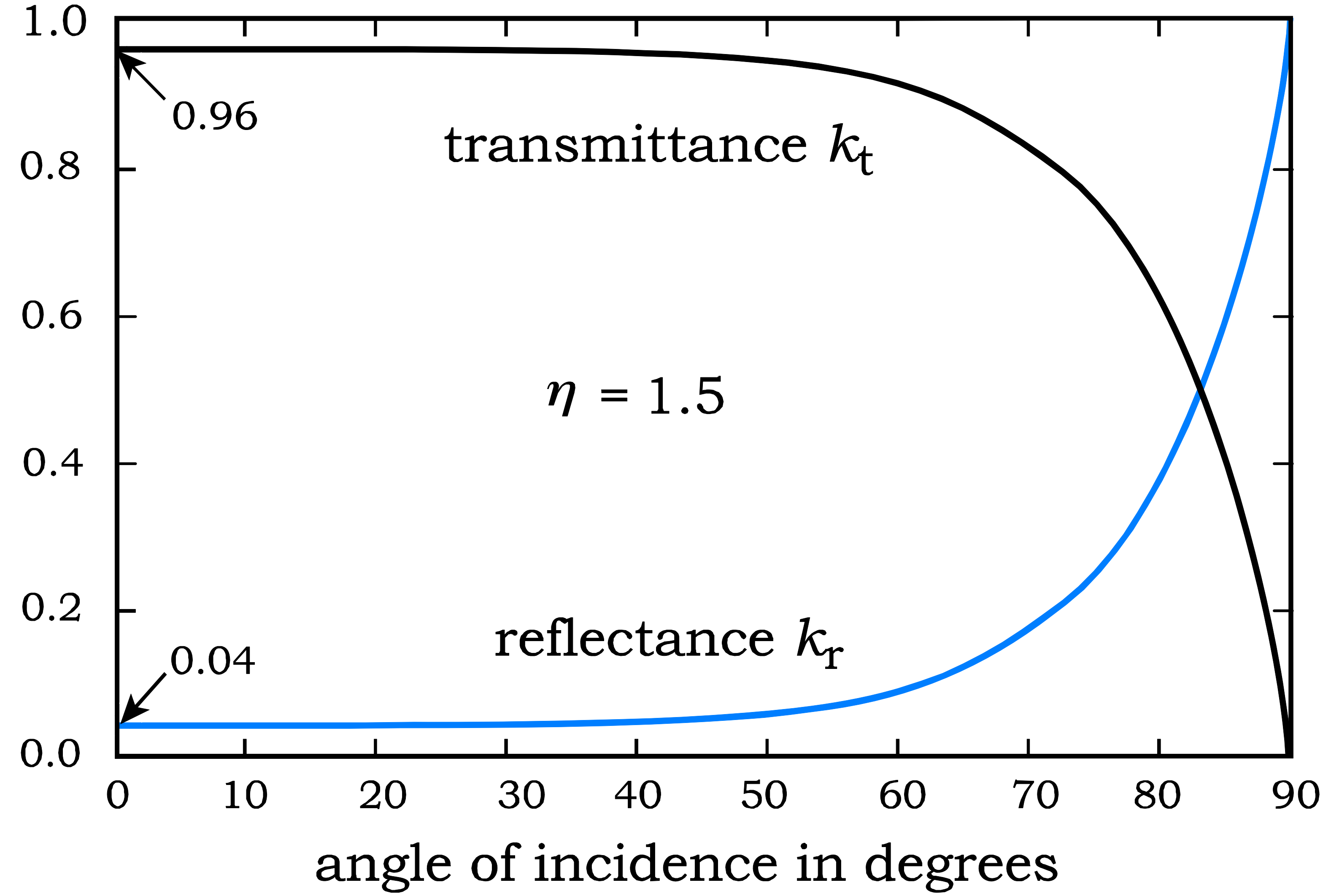
$$r_{\parallel} = \frac{\eta - 1}{\eta + 1}$$

$$r_{\perp} = -\frac{\eta - 1}{\eta + 1}$$

$$k_r = \frac{\eta - 1^2}{\eta + 1^2}$$

$$k_t = \frac{4\eta}{n + 1^2}$$

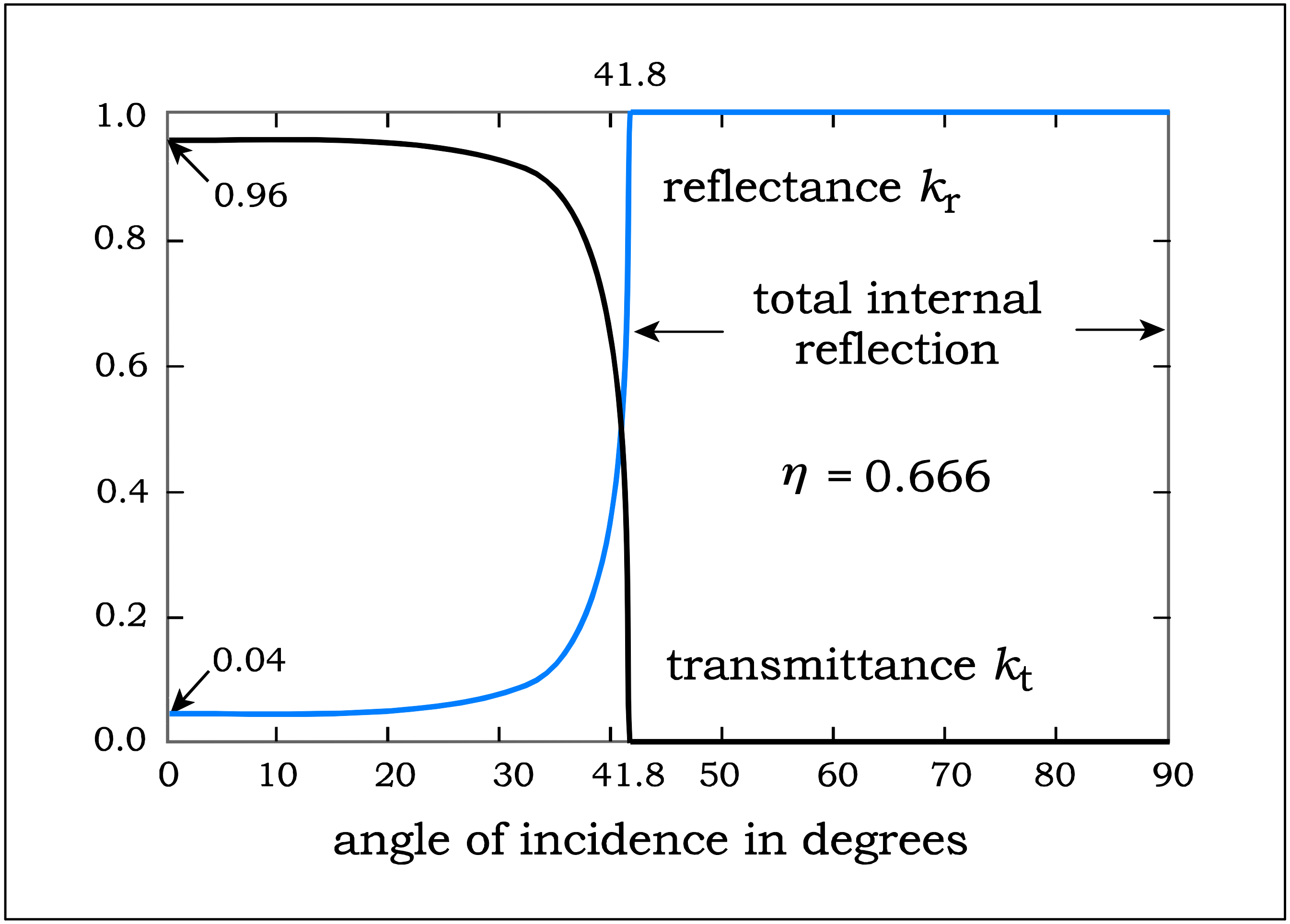
- When perpendicular to the normal (Grazing Incidence)
  - kr = 1
  - kt = 0



1.0
0.8
0.6
0.4
0.2
0.0
0.96
0.04
transmittance k_t
reflectance k_r
η = 1.5
0
10
20
30
40
50
60
70
80
90
angle of incidence in degrees

Total Internal Reflection

- Fresnel Equations Not Valid Here
  - kr = 1
  - kt = 0



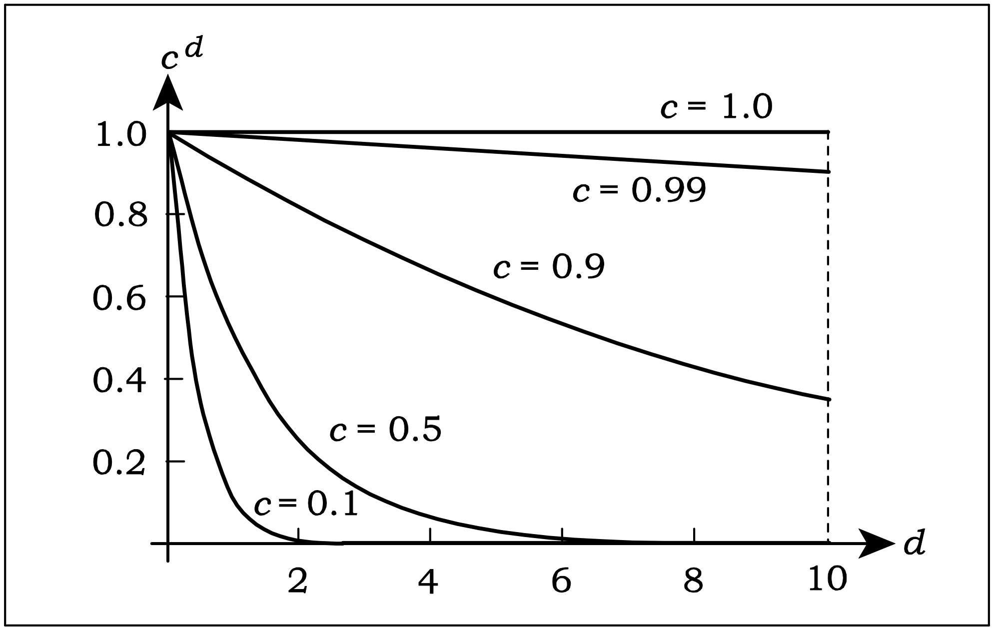
Color Filtering

- Radiance Attenutation

$$\frac{dL}{L} = -\sigma dx$$

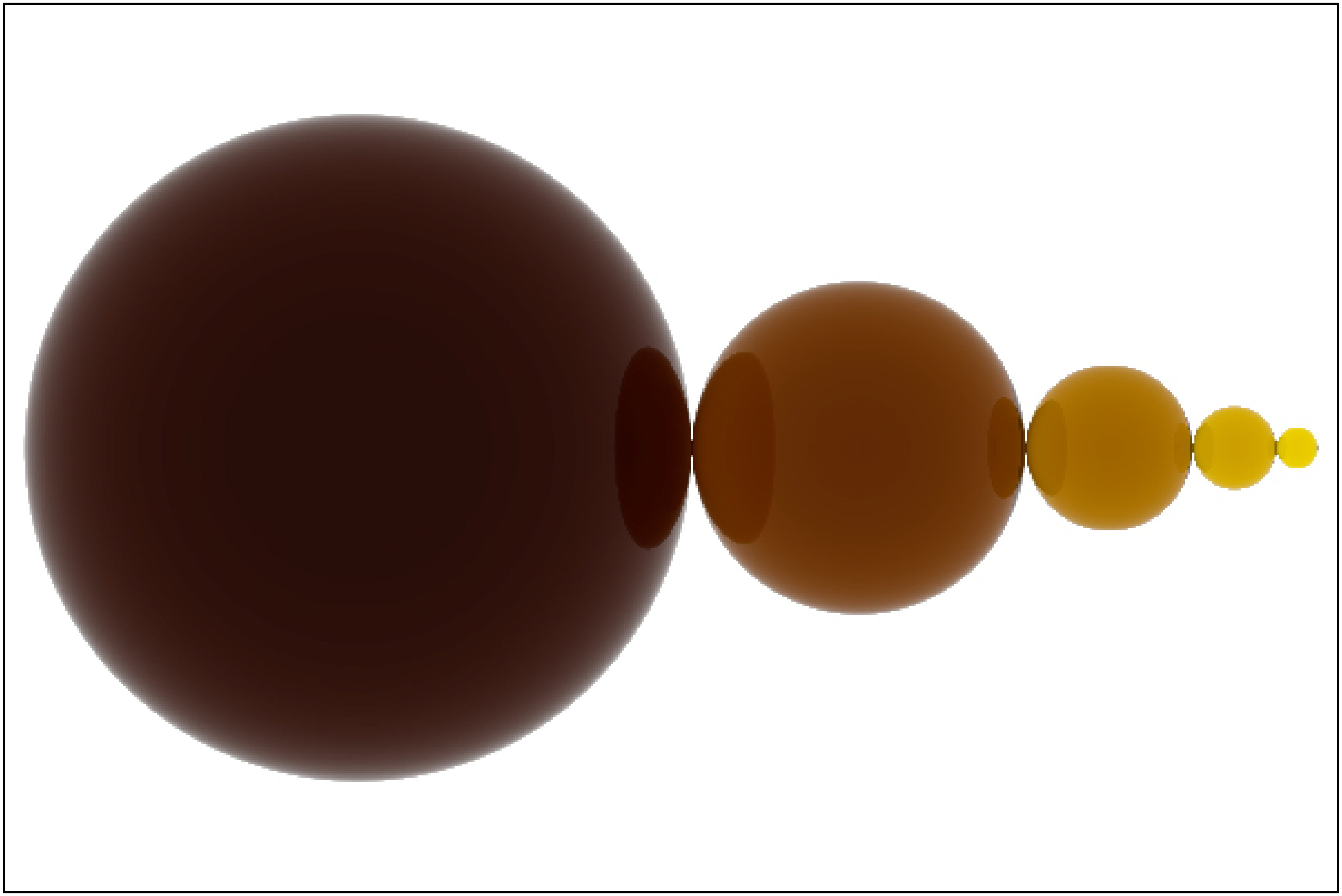
$$L(d) = L_0 e^{-\sigma d}$$

$$L(d) = c_f^d L_0$$



- Cf = Color Filter
  - No Color Filter -> RGB = (1,1,1)
  - Green Tint Color Filter -> (.9,1,.9)
    - note - .9 depends on your coordinate system

Color Filtered Spheres



Implementation

- Implement DielectricTransparentMaterial
- Heirarchy
  - IMaterial
  - Abstract Material
    - AbstractRetransmittedMaterial
      - AbstractReflectiveMaterial
        - PerfectSpecular
        - GlossySpecular
      - AbstractTransparentMaterial
        - SimpleTransparentMaterial
        - DielectricTransparentMaterial
    - Phong
    - Matte

Implementation Continued

- Memory
  - n_{in}
- Function
  - Hit
    - Obtain - Ray->n_{out}
    - Compute Fresnel Reflectance and Transmission
    - Compute Reflected Ray and Transmitted Ray (ch27)
    - Compute Color
      - Trace the Transimttance
        - Set Ray->n_{out} to n_{in}
        - Return ColorTraced * Color Filter^distance to hit point
      - Trace the Reflectance
        - Normal Perfect Specular Trace
      - Combine the Colors with kd and kf

Triangle Meshes

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C:\Users\Nik Deapen\Desktop\Chapter28\Ray Traced Images 28\Figure28.12(b).jpg

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Meshes

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C:\Users\Nik Deapen\Desktop\Chapter28\Ray Traced Images 28\Figure28.13(a).jpg

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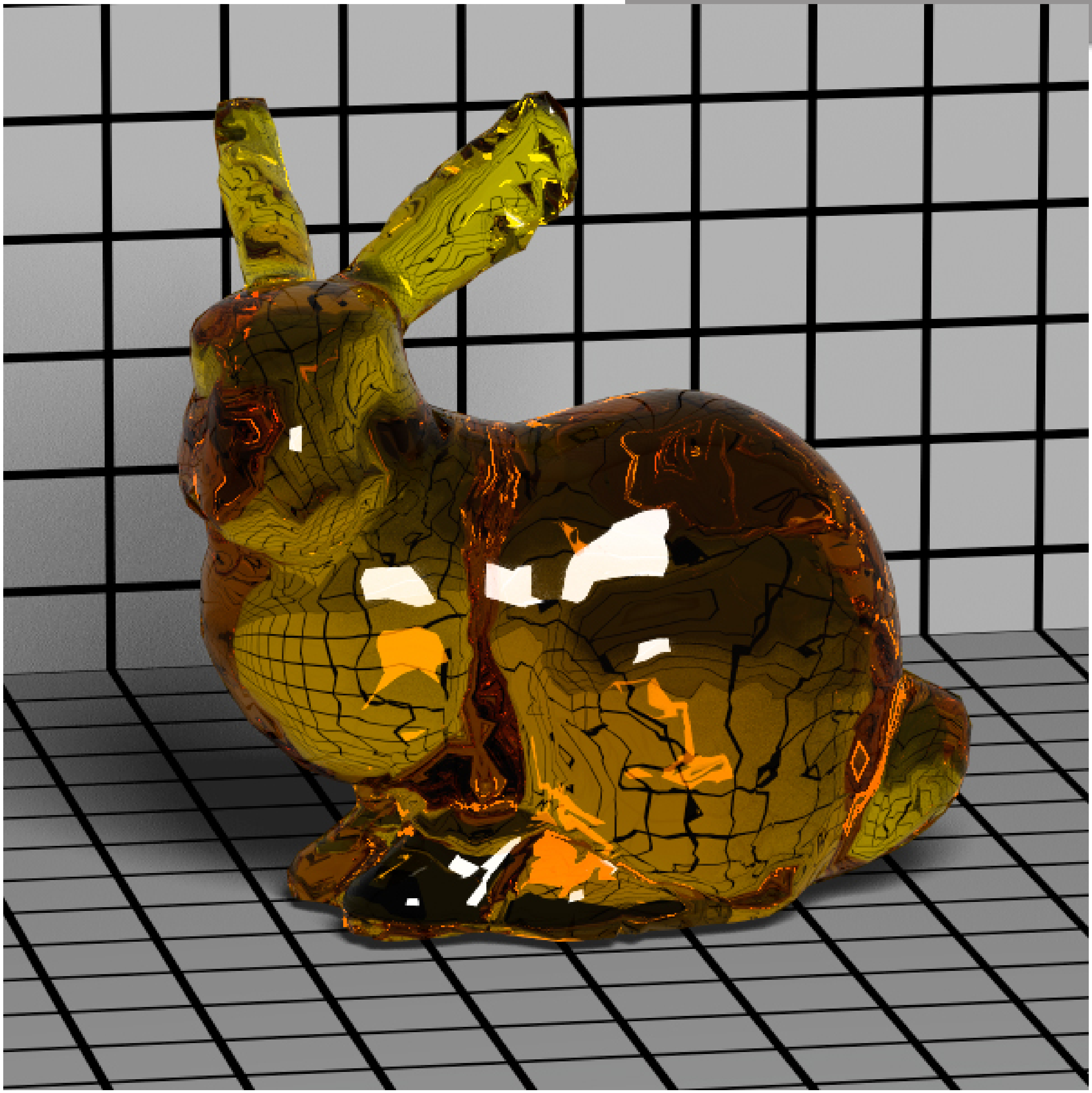
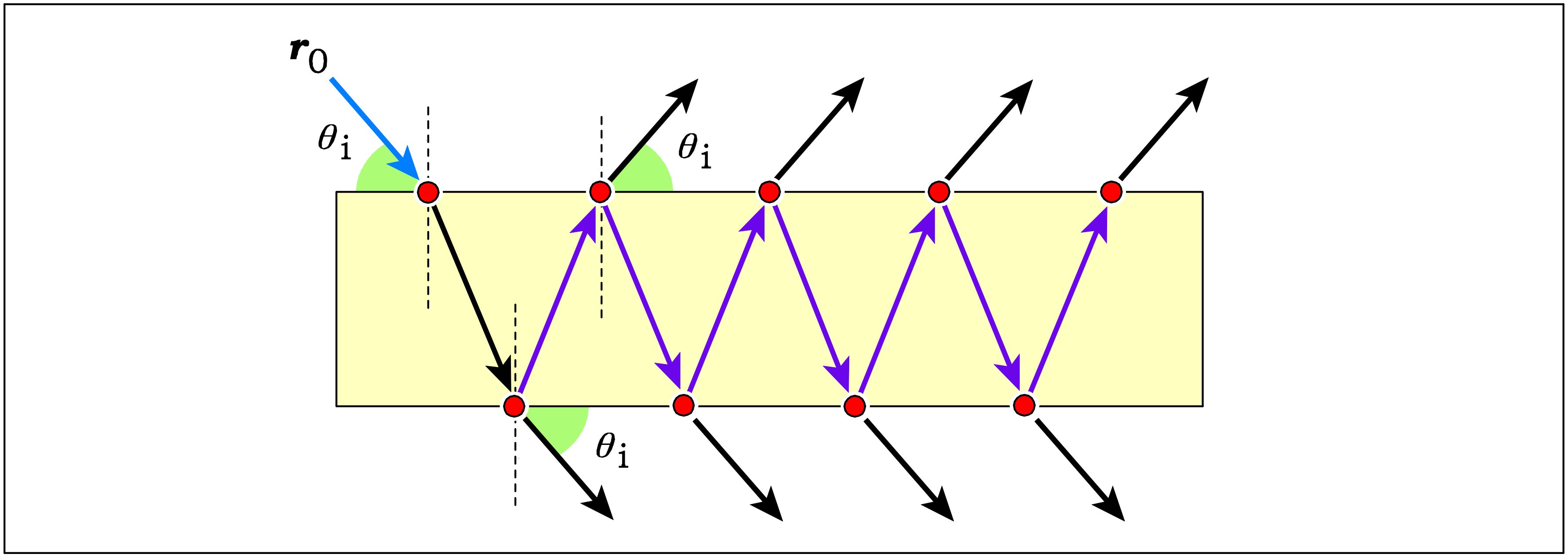
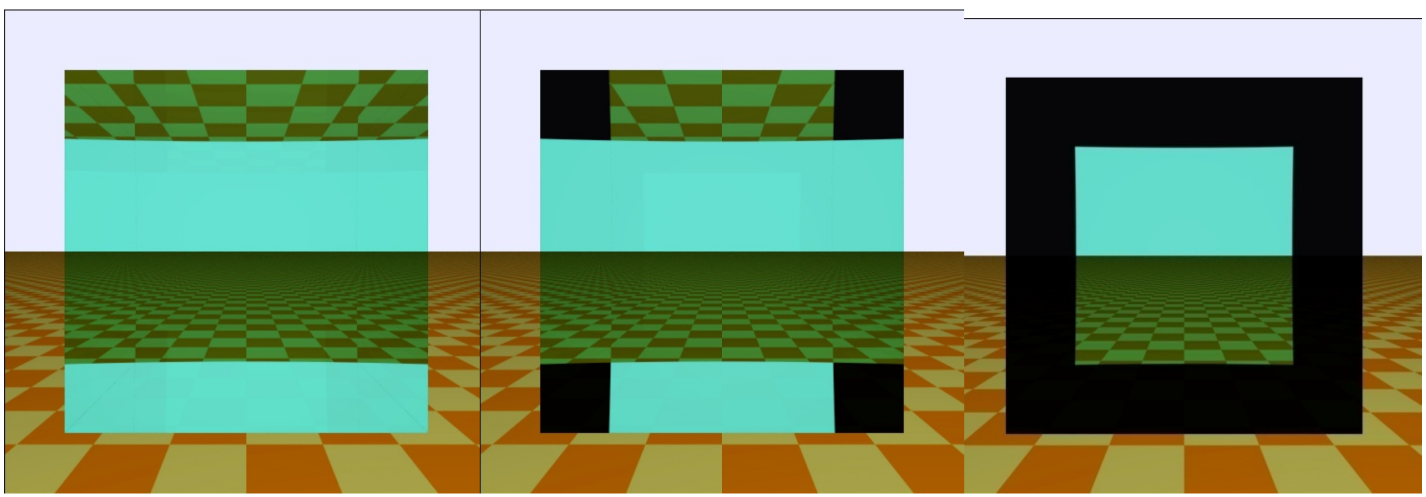
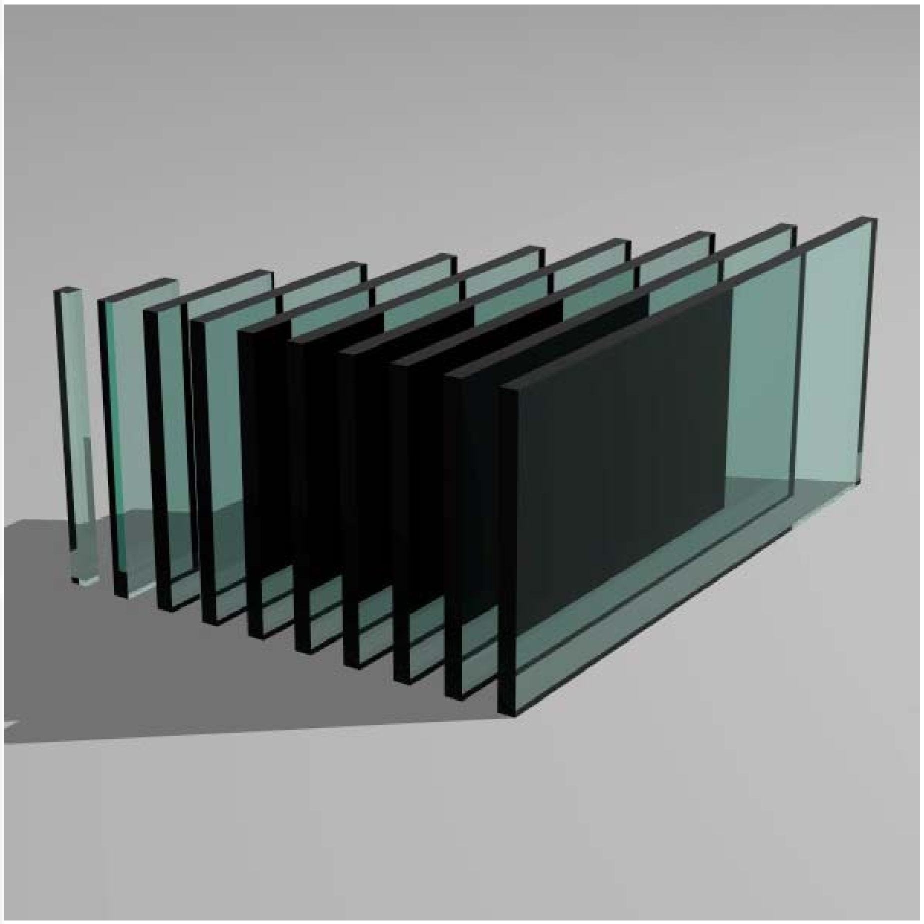
Area Lights

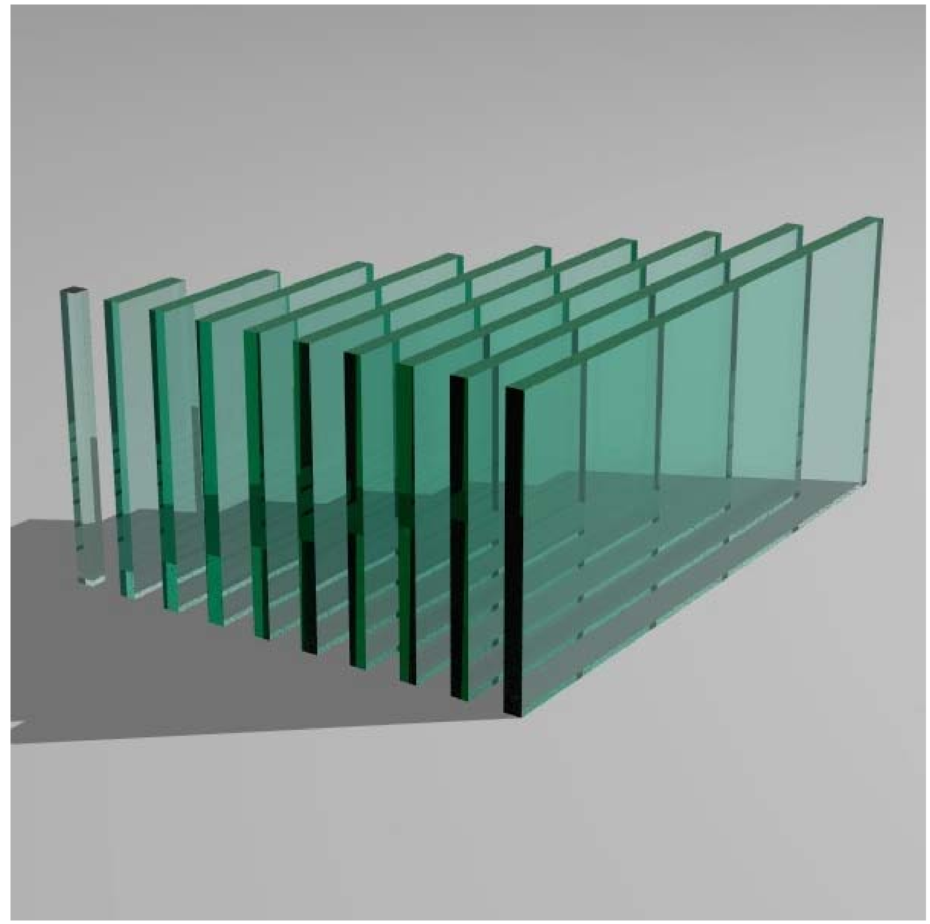


Boxes and Glass Pane (Skipping Most Theory)





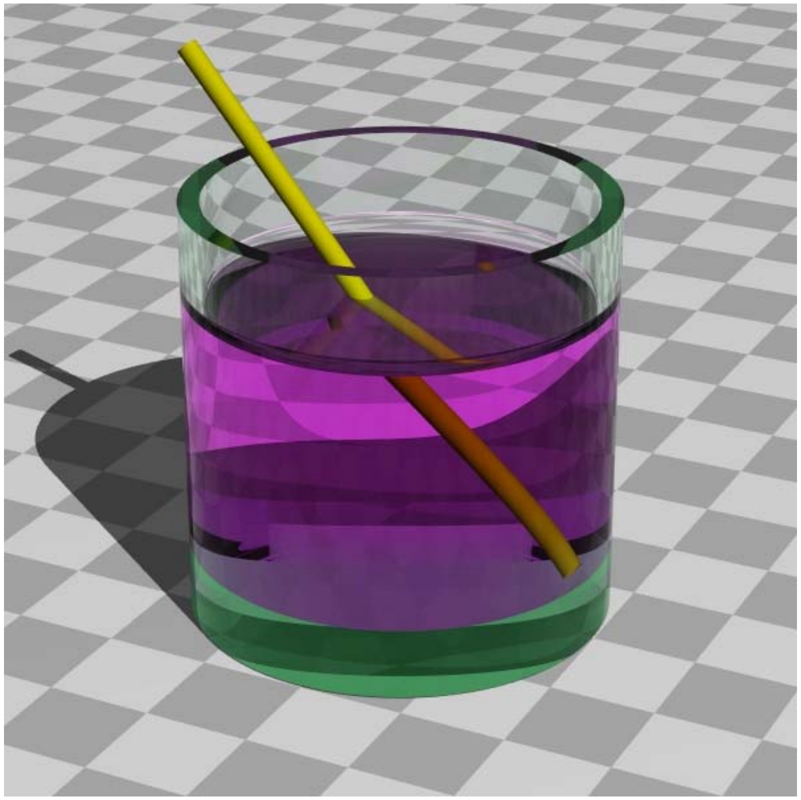


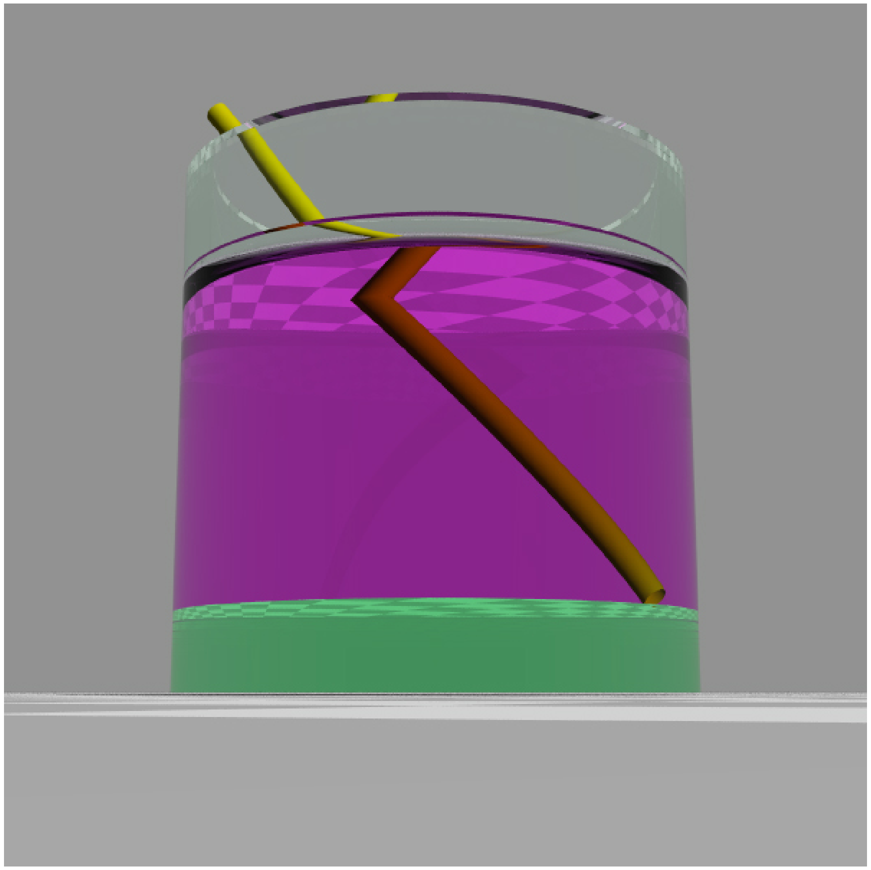


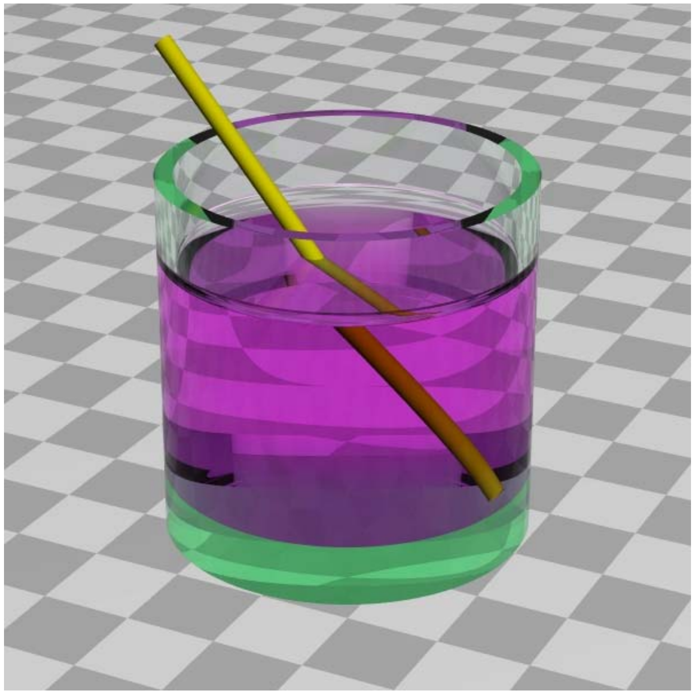
Glass of Water (or Beer)

- Cannot model seperately
  - Not with his framework
- Why?
  - Need a perfect transition to Glass and Water
    - to give η
- Model as a single compound object
  - Cylinders and Disk
  - Cylinders and Part Tori
- Fishbowls modeled the Same Way

Glass of Water







Photon Mapping and Caustics

- Algorithm
- Photons
- Photon Emission
- Photon Tracing
- Storage and Retreival

2-Pass Algorithm

1. Send the Photons out from the Lights
2. Trace the scene, gather photons to compute radiance flux at each point

What is a Photon?

- Position
  - not tied to an object
- Color
  - Color of the photon (usually white)
- Angle
  - direction the photon was traveling

```
stuct photon {  (given by Jensen)
    float x,y,z;            // position
    char p[4]               // color packed as 4 chars
    char phi, theta,        // compressed incidence dir
    short flag;             // flag used by kd tree
}
```

Photon Emission

- Point Lights
  - Pick a Random Direction
    - Not as easy as picking a (rho, theta)
- Area Lights
  - Pick a Random Point
  - Pick a Random Direction (Cosine Distribution)
- Projection Maps
  - Yes or No Projections
  - Specific Projections

Photon Tracing

- Same as Ray Tracing
  - (and global illumination)
- Bouncing
  - If ray hits a non-reflective object it can bounce
    - in a direction given by the objects BRDF
    - with a probability (k) given by the BRDF
      - the power of the reflectance
      - this makes all the photons have the same power

Photon Storage and Retreival (KD Tree)

- Construction
  - After all the photons have been traced
  - Algorithm
    - Take a midpoint of all the photons in a direction
    - Split the tree at this point
    - Recursively iterate until some depth
      - depends on how many photons you want per bucket
- Retreival
  - Algorithm
    - Get the bin with the given hit point
    - if all the n closest are in the bin
      - return those
    - Get all the bins around it (8)
      - return the n closest from all 27

Radiance Estimate

- Collection
  - Sphere – N Closest within a sphere
  - Disk – N Closest within a disk
    - (with a given normal)
- Filtering
  - Cone
    - d / kr
      - d = distance
      - r = maximum distance
  - Gaussian
    - <<enter really complex Gaussian formula here>>

Participating Media

- Color Filtering
- Ray Marching
  - Adaptive
    - dx = log(rand()) / sigma(density(x))
- Volume Photon Map

Optimizations

- Exclude Direct Illumination

References

- Ray Tracing From the Ground Up
  - Kevin Suffern
- Realistic Image Synthesis Using Photon Mapping
  - Henrik Wann Jensen