CMSC 435
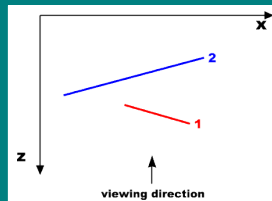## Introductory Computer Graphics
More Illumination

Penny Rheingans

UMBC

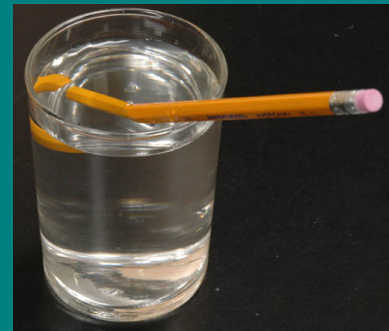# Advanced Illumination Topics

- Transparency
- Light source energy
- Surface Physics
- BRDF
- Incidence Angle Effects
- Anisotropic Effects
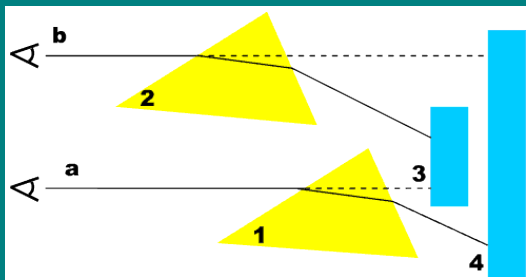- Wavelength Dependent Effects
- Layered Surfaces

Filtered Transparency

- Intensity
  - $I_f = I_{f1} + k_{tf}O_{tf}I_{f2}$
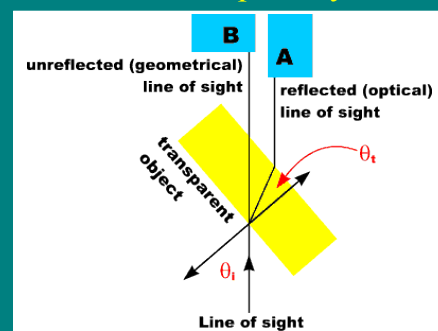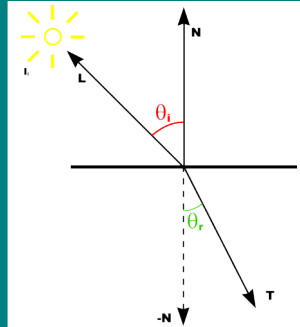- Must composite back to front (or front to back
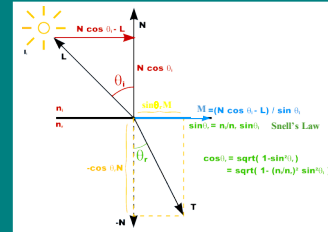

Refraction

Refractive Transparency

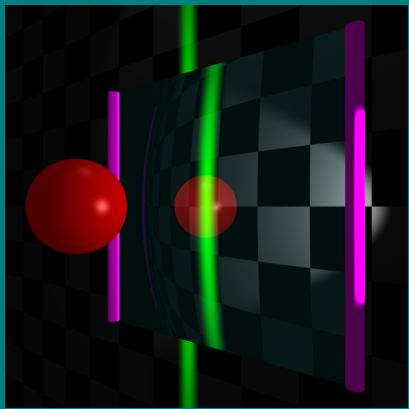# Refractive Transparency

Calculating Refraction Vector

Calculating Refraction Vector

$$T = \sin\theta_r M - \cos\theta_r N$$
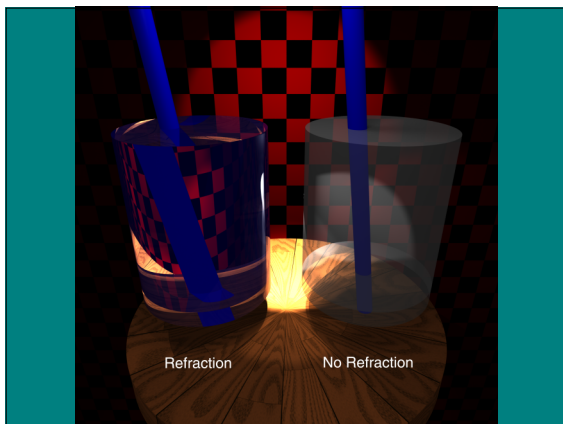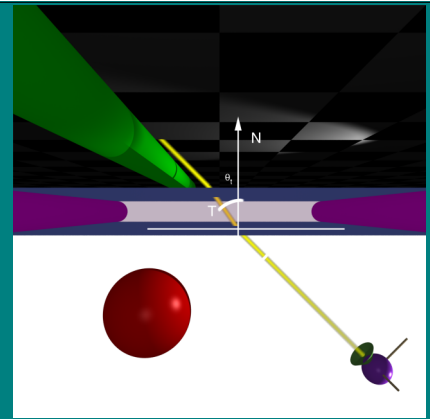$$= (\sin\theta_r / \sin\theta_i)(N\cos\theta_i - L) - \cos\theta_r N$$
$$= ((n_i/n_r)\sin\theta_i)/\sin\theta_i (N\cos\theta_i - L) - \cos\theta_r N$$
$$= ((n_i/n_r)(N\cos\theta_i - L)) - \cos\theta_r N$$
$$= ((n_i/n_r)\cos\theta_i - \cos\theta_r)N - (n_i/n_r)L$$
$$= ((n_i/n_r)\cos\theta_i - \sqrt{1 - (n_i/n_r)^2\sin^2\theta_i})N - (n_i/n_r)L$$
$$= ((n_i/n_r)(N\bullet L) - \sqrt{1 - (n_i/n_r)^2(1-(N\bullet L)^2)})N - (n_i/n_r)L$$

Side

Top

Refraction   No Refraction

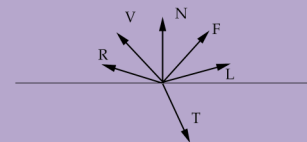## Total Illumination at a Point (single light source)

$$I = I_{local} + I_{reflect} + I_{transmit}$$
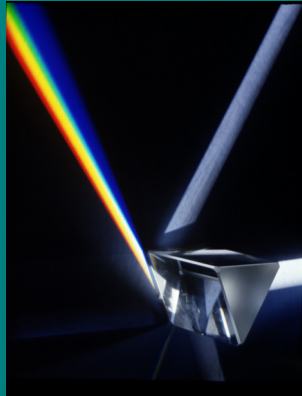
$$I_{local} = k_a I_a + k_d I_p(N\bullet L) + k_s I_p(R\bullet V)^n$$

$$I_{reflect} = k_s I_f$$
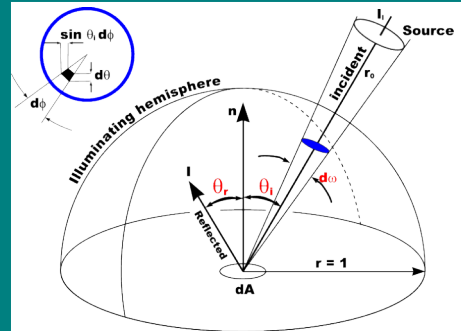where I_f = intensity evaluated along reflected ray F

$$I_{transmit} = k_t I_t$$
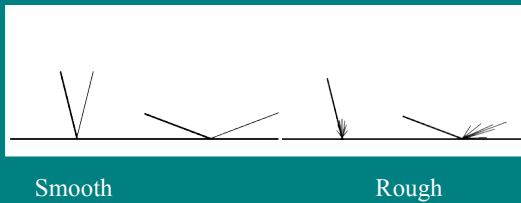where I = intensity evaluated along refracted ray T
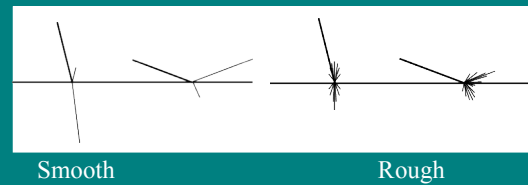
Refraction by Wavelength

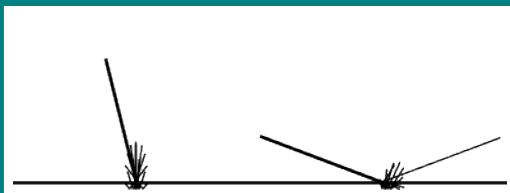# Light Source Energy

Surface Physics

- Conductor (like metal)

Smooth   Rough

Surface Physics

- Dielectric (like glass)

Smooth   Rough

Surface Physics
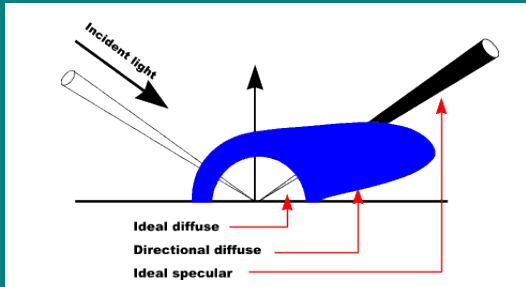
- Composite (like plastic)

Reflectance Model

- Cook and Torrance, '81
- Incoming energy of incident light beam

$$E_i = I_i(N \cdot L)d\omega_i$$

where I_i : incident intensity

$d\omega_i$: solid angle of beam

- Bidirectional reflectance
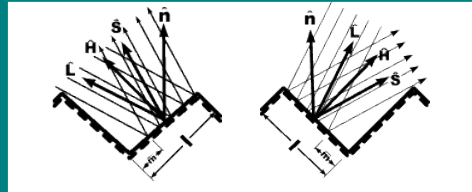
$$R = I_r/E_i$$

- Reflected light from each light source

$$I_r = RE_i$$

BRDF

Incident light
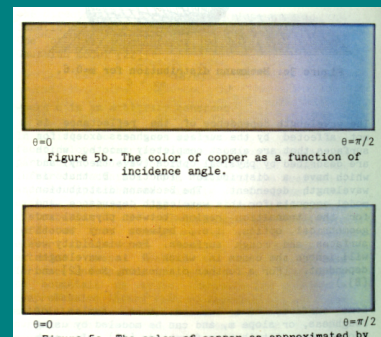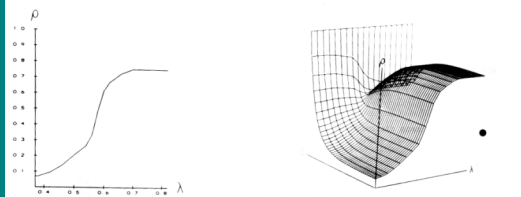
Ideal diffuse
Directional diffuse
Ideal specular

Directional Distribution

- Assume surface consists microfacets
  - $R_s = F/\pi * D/(N\cdot L) * G/(N\cdot V)$
  - F: Fresnel term
  - G: geometric attenuation factor (masking and shadowing)
  - D: facet slope distribution function

Spectral Composition

- All components of reflectance depend on wavelength
- Reflectance spectra of materials from measurements
- Spectral energy distribution of reflected light from spectral distributions of both incident light and reflectance
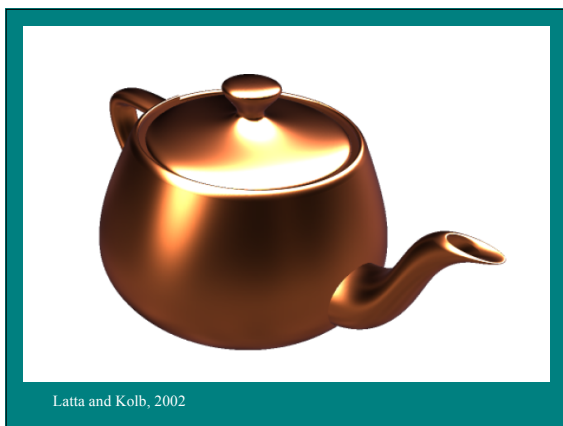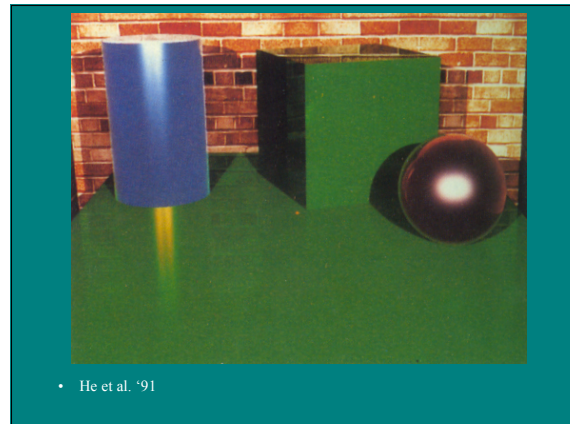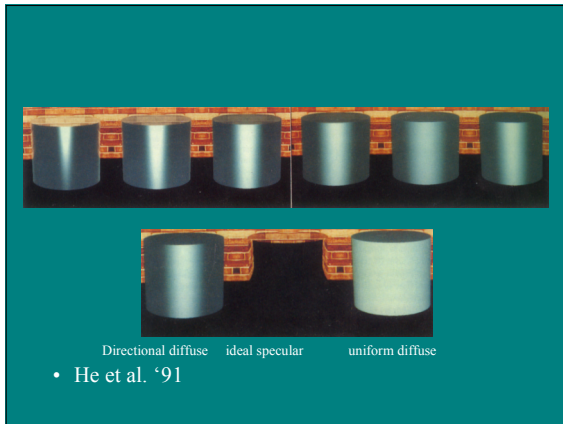

$\theta=0$ $\theta=\pi/2$

Figure 5b. The color of copper as a function of incidence angle.

$\theta=0$ $\theta=\pi/2$

- Cook and Torrance '81

- Cook and Torrance '81

Carbon   Red Rubber   Obsidian   Lunar Dust   Olive Drab   Rust

Bronze   Tungsten   Copper   Tin   Nickel   Stainless Steel

- Cook and Torrance, '81

Directional diffuse   ideal specular   uniform diffuse

- He et al. '91

- He et al. '91

Latta and Kolb, 2002
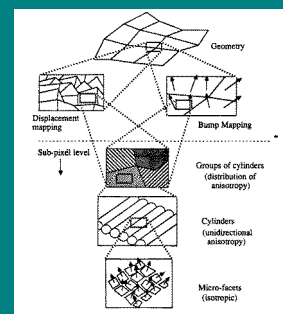

Latta and Kolb, 2002

Anisotropy

- Oriented light reflection not solely dependent on normal/light relationship
- Examples
  - oriented components: fur, hair, grass, fibers
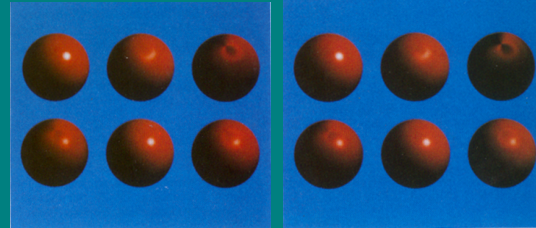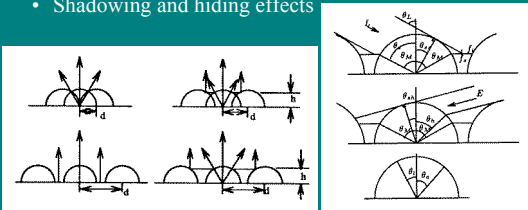 - oriented defects: burnished metal, scratches

Hierarchy of Geometric Models

- Geometry
- Displacement
- Bump mapping
- Frame bundles
- Cylinders
- Micro-facets

Cylindrical Scratches

- Use positive and negative cylinders to model grooves of anisotropic surface
  - d: distance
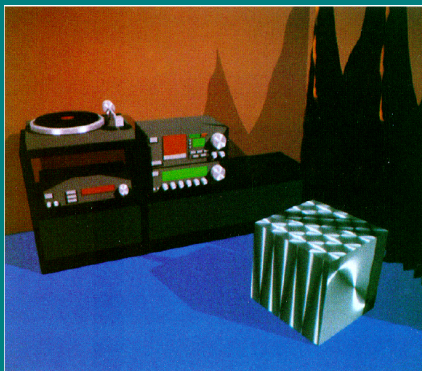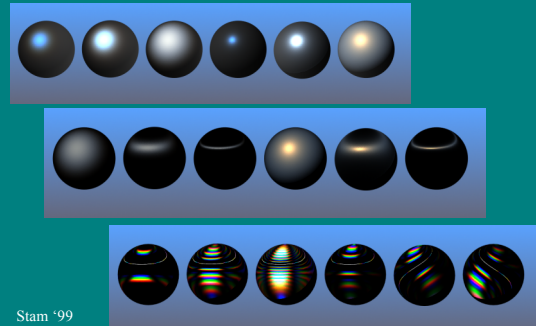 - h: height
- Shadowing and hiding effects

- Poulin and Fournier '90

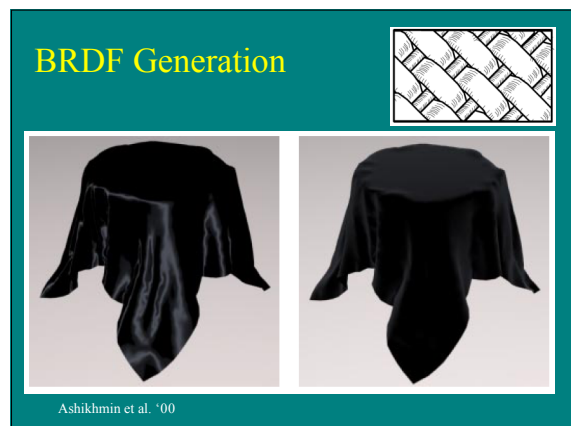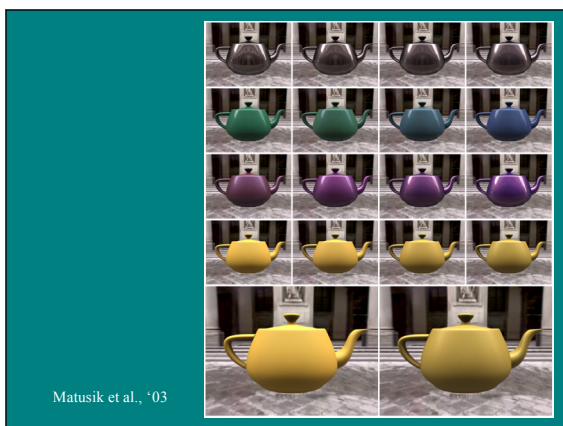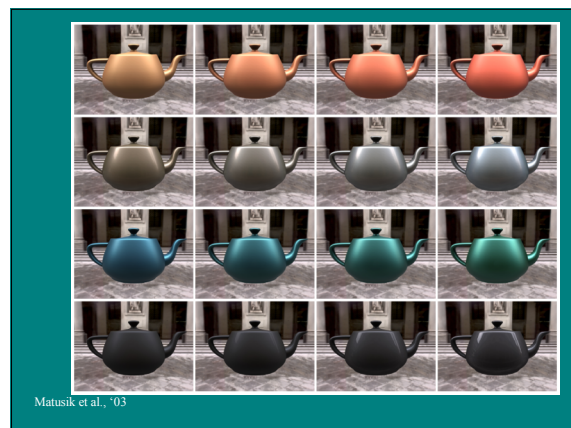- Poulin and Fournier '90

- Poulin and Fournier '90

- Poulin and Fournier '90

Diffraction Shaders

Stam '99

Stam '99

BRDF Acquisition
Matusik et al., '03
Figure 5: Pictures of 100 of our acquired materials.

Matusik et al., '03

Matusik et al., '03

Matusik et al., '03

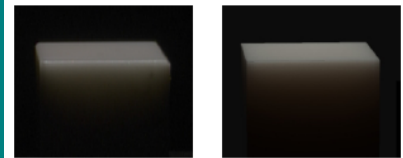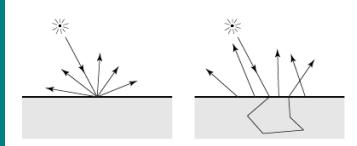BRDF Generation
Ashikhmin et al. '00
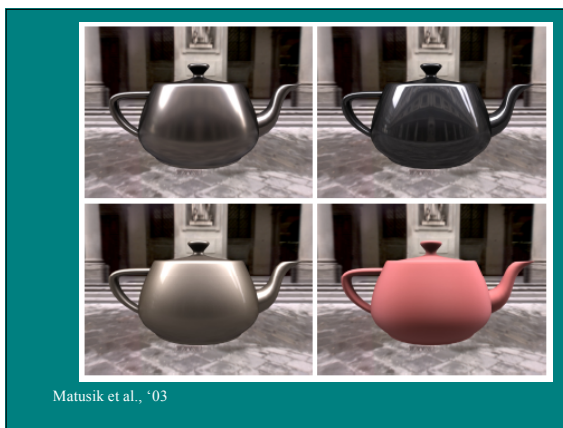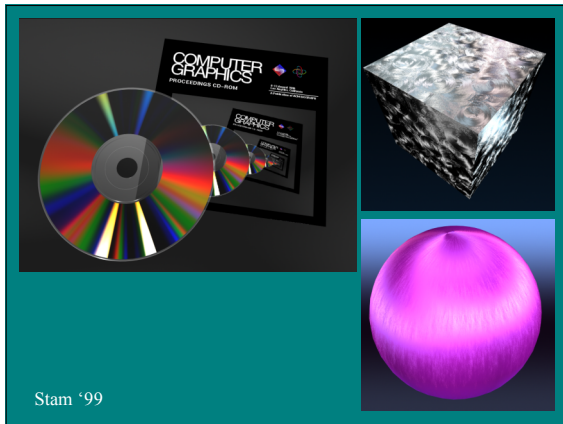
Slide: **Layers and Subsurface Scattering**
- Translucent materials require BSSRDF

Jensen et al, '01

Slide: BRDF   BSSRDF

Jensen et al, '01

Jensen et al, '01

BRDF

BSSRDF

Jensen et al, '01

Slide: **Comparisons to Reality**
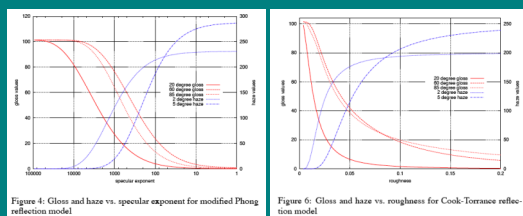- Correspondence between appearance standards and illumination parameter

Figure 4: Gloss and haze vs. specular exponent for modified Phong reflection model

Figure 6: Gloss and haze vs. roughness for Cook-Torrance reflection model

Westlund and Meyer, '01

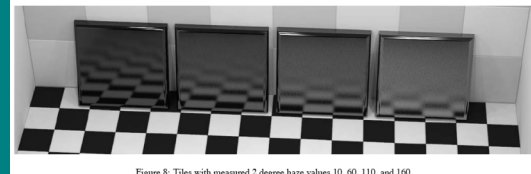Figure 7: Tiles with measured 20 degree specular gloss values 80, 60, 40, and 20

Figure 8: Tiles with measured 2 degree haze values 10, 60, 110, and 160

Westlund and Meyer, '01

Westlund and Meyer, '01