Local Reflection Models

Illumination Thus Far …

- Simple Illumination Models
  - Ambient + Diffuse + Attenuation + Specular
- Additions
  - Texture, Shadows, …
- Used in global algs! (Ray tracing)
- Problem: Different materials
  - Plastic and metal of same "color" look different

Overview

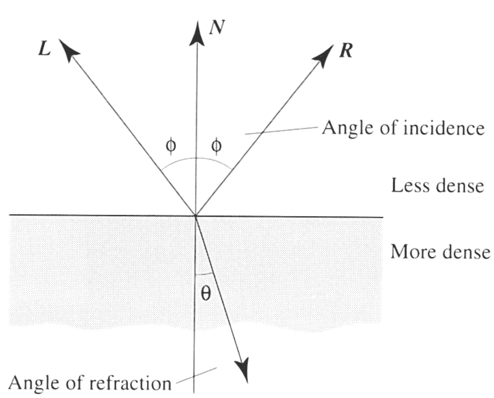
- Reflection from a perfect surface (Fresnel)
- Reflection from an imperfect surface
- BRDF's
- Diffuse and specular
  - Perfectly diffuse, empirical specular (Phong)
  - Physically-based specular (Cook&Torrance)
  - Physically-based diffuse (Hanrahan&Kreuger)

Reflection from a perfect surface (i.e., a perfect mirror)

- Fresnel's Formula $F = \frac{1}{2}\left\{\frac{\sin^2(\phi-\theta)}{\sin^2(\phi+\theta)} + \frac{\tan^2(\phi-\theta)}{\tan^2(\phi+\theta)}\right\}$

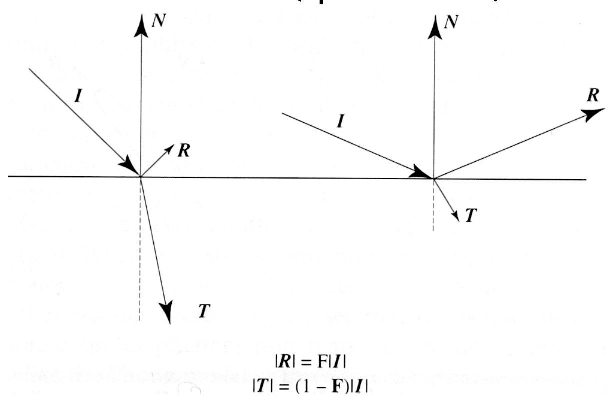
$\sin\Theta = \sin\Phi/\mu$

μ is the index of refraction



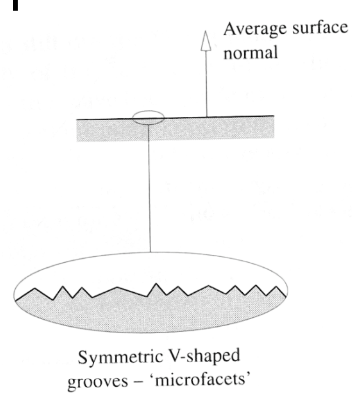
Reflection and Transmission

- Relates ratio of reflected/transmitted light
  - Function of incident dir, polarization, material



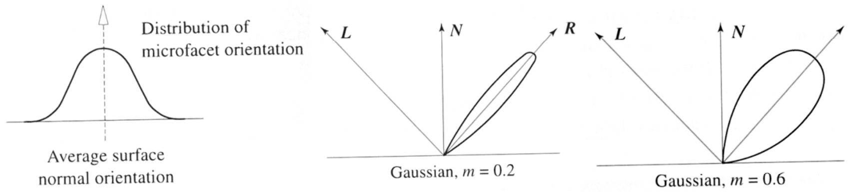
Reflection from an imperfect surface

- Surfaces are not optically perfect
  - Microgeometry
- Simulate microgeometry,
  - Use Fresnel eq
  - Microfacets (v-shaped pits)



Reflection from an imperfect surface

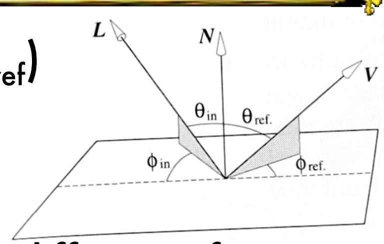
- Parameterized lobe describes reflection over small area



- Ignores dust, scratches, etc.

BRDF (Bi-directional Reflectance Distribution Function)

- BRDF = $f(\Theta_{in}, \Phi_{in}, \Theta_{ref}, \Phi_{ref})$
  - Function of surface orientation as well as incident orientation



- Fig 7.4: materials have diff BRDF for each wavelength
  - Never 1
  - 3 too simple(Phong)

Anisotropic vs. Isotropic surfaces

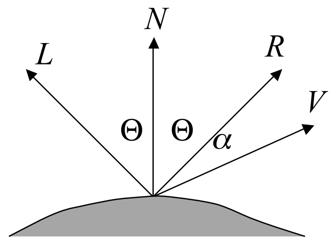
- Isotropic: ignore Φ
- Anisotropic: f() depends on Φ
  - Grooved surfaces, such as brushed metal

Diffuse + specular: a simplification!

- Specular models typically simplistic
  - e.g., perfect mirror
- Diffuse is like powder, clay, …
  - Phong adds spread
  - Cook & Torrance add physically-based spec.
  - Hanrahan & Kreuger add phys-based diffuse

Perfect diffuse, empirical specular (Phong)

- Recall: $I = I_a k_a O_d + f_{att} I_p [\, k_d O_d (N \cdot L) + k_s (R \cdot V)^n]$
- Diffuse: Lambertian
  - $\cos(\Theta_{in})$
- Account for viewer position
  - $\cos(\Theta_{ref})$
- Amount of specular light doesn't vary with Θ_{in}
- BRDF = $f(\Theta_{in}, \Theta_{ref})$

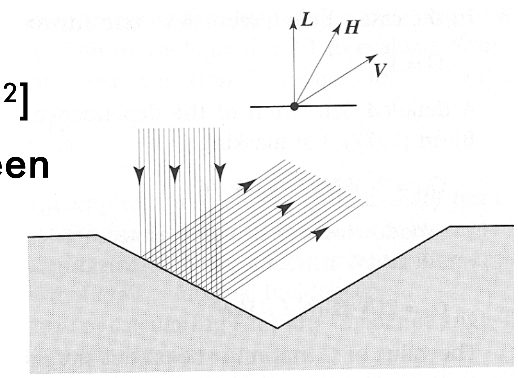


Physically-based Specular Component
(Blinn '77, Cook and Torrence '82)

- Change specular highlight based on
  - Material (e.g., color of highlight changes)
  - Angle of incidence of light (Θ_{in})
- Recognize that highlight is reflected light
  - Distorted by geometry (Phong does this)
  - Angle and color of light (e.g., metal vs non-)
- Cost been prohibitive in fast 3D
- Approach: Model "micro-geometry" of surface

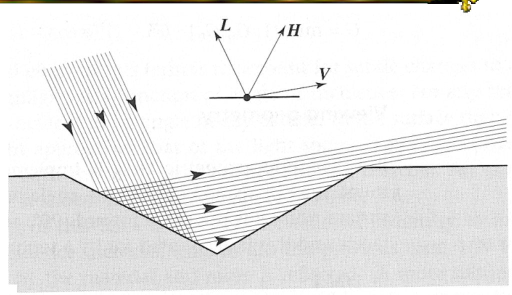
Micro-Geometry of Surface: "D"

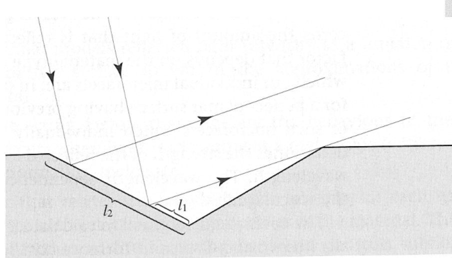
- Statistical model geometry
  - D=amount of light emerging for some Θ_{in}
- E.g., if Gaussian
  - $D = k \exp[-(\alpha/m)^2]$
- α = angle between H and N

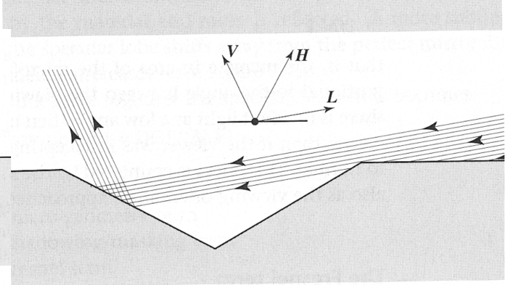


Shadowing and Masking: "G"

- $G = 1 - l_1/l_2$
  (derivation using N, H, L, V in book)







Viewing Geometry

- As $N \cdot V$ increases, more microfacets seen
  - Proportional to $1/(N \cdot V)$
- More light reflected at low angles
  - Countered by shadowing

Fresnel Term: "F"

- Recall: amount of light reflected vs. absorbed
- How to get F over all wavelengths?
  - Measure F_0, determine μ
  - Compute F using Fresnel equation
- Reflected intensity increases with angle from N

Summary: Physically-based Specular Term

- Specular component = $DGF/N \cdot V$
- Factors for
  - Physical nature of surface
  - Glare (2 interacting terms)
  - Optical effects of each mirrored surface to control shape and intensity of highlight

Summary: Physically-based Specular Term

- BRDF = $sR_s + dR_d$ (where $s+d=1$)
  - R_s is specular, R_d is separate diffuse
  - E.g. metal (d=0, s=1), plastic (d=0.9, s=0.1)
- Still ignores Φ_{in}!
- BRDF = $f(\Theta_{in},\Theta_{ref},\Phi_{ref})$

Physically-based Diffuse

(Hanrahan and Kreuger '93)

- Physical simulations must be based on subsurface scattering
  - Light absorbed, bounced around, emitted
  - Incident white light "filtered" by material
- Lots of effects require it
  - Skin, leaves, snow, sand, …
- Supports anisotropic materials
  - Subsurface scattering uses physical properties