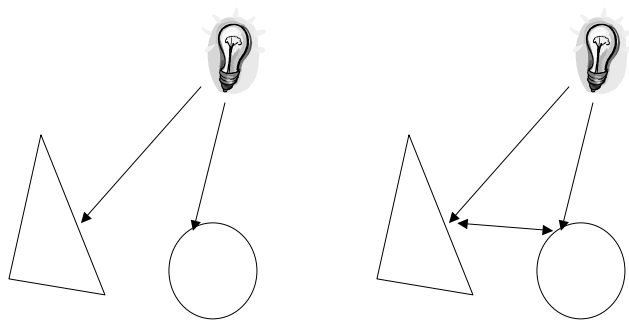
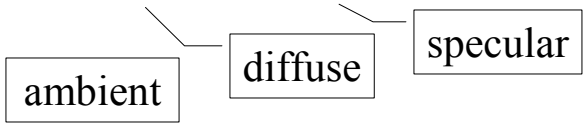
Local Reflection Models

Local vs. Global



Phong Reflection Model

- I = Ka*Ia + kd*Id + Ks*Is



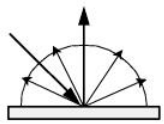
- Not completely correct, but good enough.

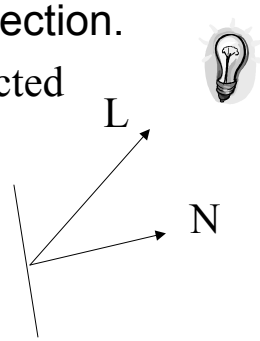
Ambient Component

- Accounting for light scatter around.
- Ia is constant.

Diffuse Component

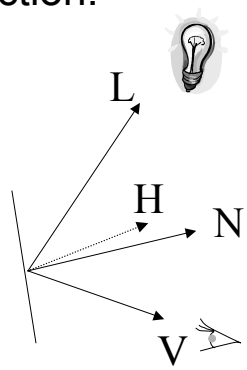
- $Id = Ii * N \cdot L$
- Not affected by viewing direction.
  - i.e., incoming light is reflected to all directions.





Glossy (Specular) Component (Phong Reflection Model)

- To model imperfect reflection.
- $Is = Ii(N \cdot H)^n$



Summary of Phong Reflection Model

- $I = Ka*Ia + kd*Id + Ks*Is$

  $= Ka*Ia + \{Kd*(N \cdot L) + Ks*(N \cdot H)^n\} * Ii$

- Where is color? Set Ka and Kd for RGB.

  $Ir = Ka\_r*Ia + \{Kd\_r*(N \cdot L) + Ks\_r*(N \cdot H)^n\} * Ii$

  $Ig = Ka\_g*Ia + \{Kd\_g*(N \cdot L) + Ks\_g*(N \cdot H)^n\} * Ii$

  $Ib = Ka\_b*Ia + \{Kd\_b*(N \cdot L) + Ks\_b*(N \cdot H)^n\} * Ii$

- Ka and Kd depend on material color, Ks depends on the light (which is white in the above case).

Phong Reflection Model (continued)

- We had:

  $Ir = Kar*Ia + \{Kdr*(N \cdot L) + Ksr*(N \cdot H)^n\} * Ii$

  $Ig = Kag*Ia + \{Kdg*(N \cdot L) + Ksg*(N \cdot H)^n\} * Ii$

  $Ib = Kab*Ia + \{Kdb*(N \cdot L) + Ksb*(N \cdot H)^n\} * Ii$

- Alternatively:

  $I = \{Ka*Ia + Kd*Ii*(N \cdot L)\} * object\_color$

  $+ Ks*Ii*(N \cdot H)^n * light\_color$

"But, they all look like plastic…"

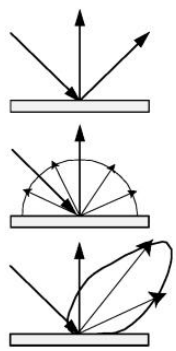
Specular Component (Cook & Torrance Model)

- Consider specular reflection as perfect reflection of micro-facets. (See Watt's Section 7.6)
- Specular=DGF/($N \cdot V$)

  D: Distribution term

  G: Geometry (shadowing and masking) term

  F: Fresnel term



D Term (Cook & Torrance)

- Modeling the distribution of micro-geometry.
- Gaussian distribution can be used:

$$D = k\, e^{-(\alpha/m)2}$$

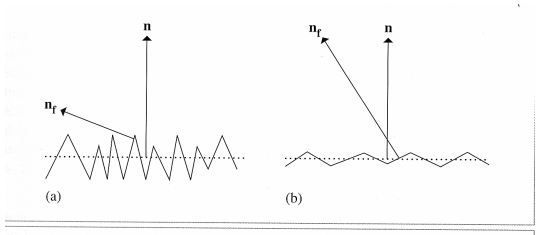


Figure 9.11: Microfacet surface models are often described by a function that gives the distribution of microfacet normals $\mathbf{n}_f$ with respect to the surface normal $\mathbf{n}$. (a) The greater the variation of microfacet normals, the rougher the surface is. (b) Smooth surfaces have relatively little variation of microfacet normals.

G Term (Cook & Torrance)

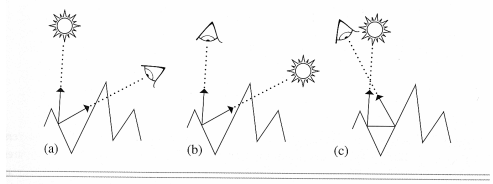
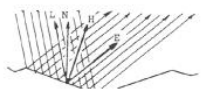
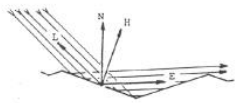


Figure 9.12: Three Important Geometric Effects to Consider with Microfacet Reflection Models. (a) *Masking*: the microfacet of interest isn't visible to the viewer due to occlusion by another microfacet. (b) *Shadowing*: analogously light doesn't reach the microfacet. (c) *Interreflection*: light bounces among the microfacets before reaching the viewer.

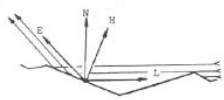
$$G = \min(G_a, G_b, G_c)$$



$$G_a = 1$$



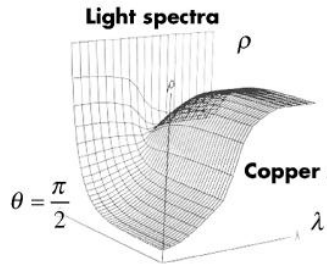
$$G_b = \frac{2(\mathbf{N}\bullet\mathbf{H})(\mathbf{N}\bullet\mathbf{E})}{(\mathbf{H}\bullet\mathbf{E})}$$



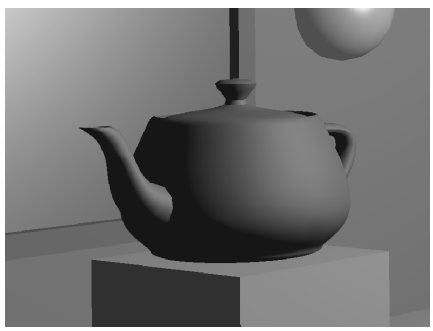
$$G_c = \frac{2(\mathbf{N}\bullet\mathbf{H})(\mathbf{N}\bullet\mathbf{L})}{(\mathbf{H}\bullet\mathbf{L})}$$

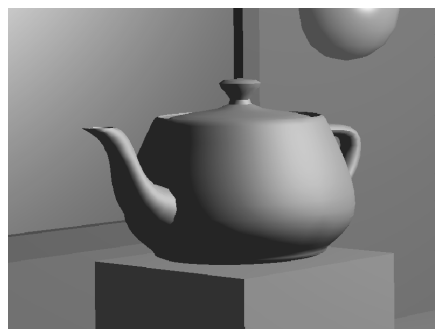
The Fresnel Term

- Color and ratio of reflected/transmitted light vary with the incident and viewing angles.
- Detailed in Pharr's 9.2.1 and Watt's 7.6.4



Reflectance of Copper as a function of wavelength and angle of incidence





From Watt's color plate Figure 7.8. These would be difficult to obtain by fine-tuning the parameters in Phong model.

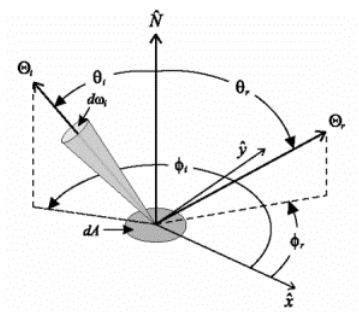
"Now, are all materials covered?"

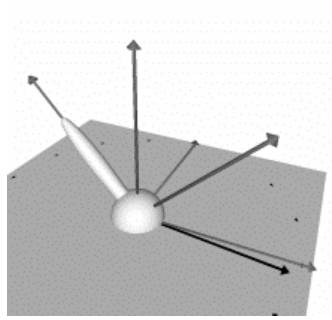
No!

Let's try a sample-based method instead…

BRDF

- BRDF=f(θ_{in}, ϕ_{in}, θ_{ref}, ϕ_{ref})=f(L,V)





Watch Out for Subtly in BRDF!

- Ask yourself these questions:
  - Why not just consider $\mathrm{N} \cdot \mathrm{H}$ as in the Phong's glossy term? (Hint: Does incidence matter?)
  - Does ϕ_{in} really matter?

  Difference between isotropic and anisotropic reflection!

Why Not Always Using BRDF?

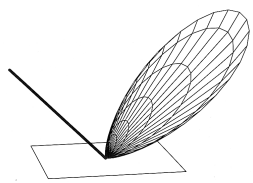
- Difficult to find a "closed form" representation of BRDF.
- The Phong model and Cook & Torrance model are approximation of BRDF.
  - They are not 100% match of BRDF, but they are easy to compute.

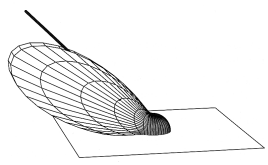
Other Reflection Models

- Pharr's 9.4: other microfacet models
  - Oren-Nayar
  - Torrance-Sparrow
  - Blinn microfacet distribution
  - Anisotropic microfacet model
- Pharr's 9.5: Lafortune model
- Models for particular materials: e.g., for finished wood (in SIGGRAPH 2005)

Lafortune Model

- Phong model assumes the glossy reflection (lobe) appears in the direction opposite to the incident light.
- This assumption is relaxed in the Lafortune model.
- Multiple lobes can be used.


(b)


(d)

Gouraud Shading and Phong Shading

- Gouraud and Phong shadings are interpolative techniques for rasterization.
  - Polygon vertices are shaded first.
  - Vertex colors are then interpolated to the interior pixels.