

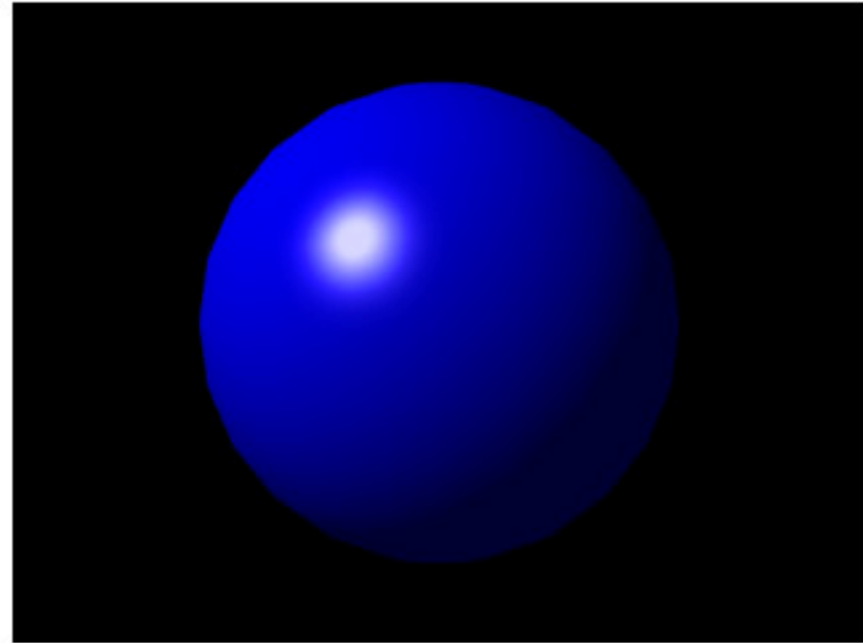
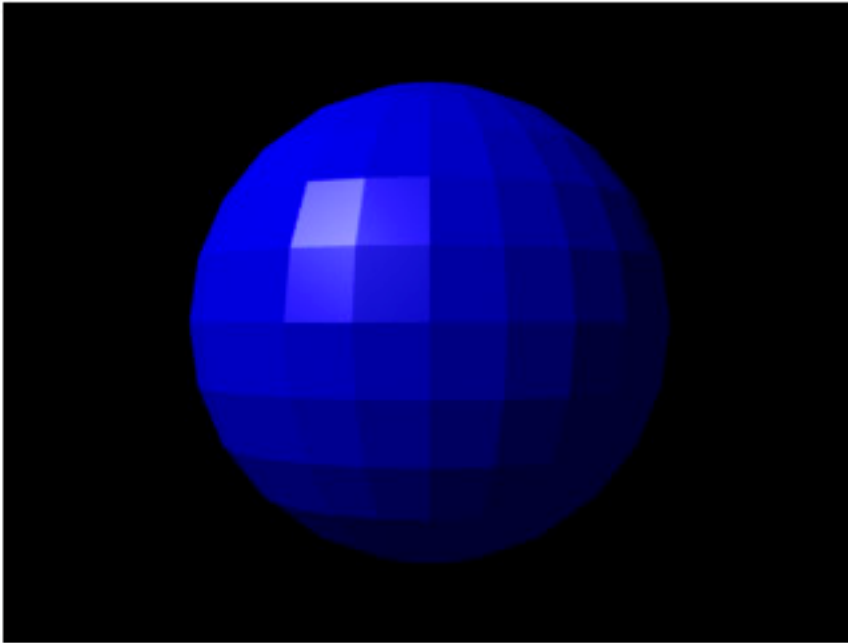
3D Computer Graphics for People in a Hurry

Shading

Professor Eric Shaffer

Shading

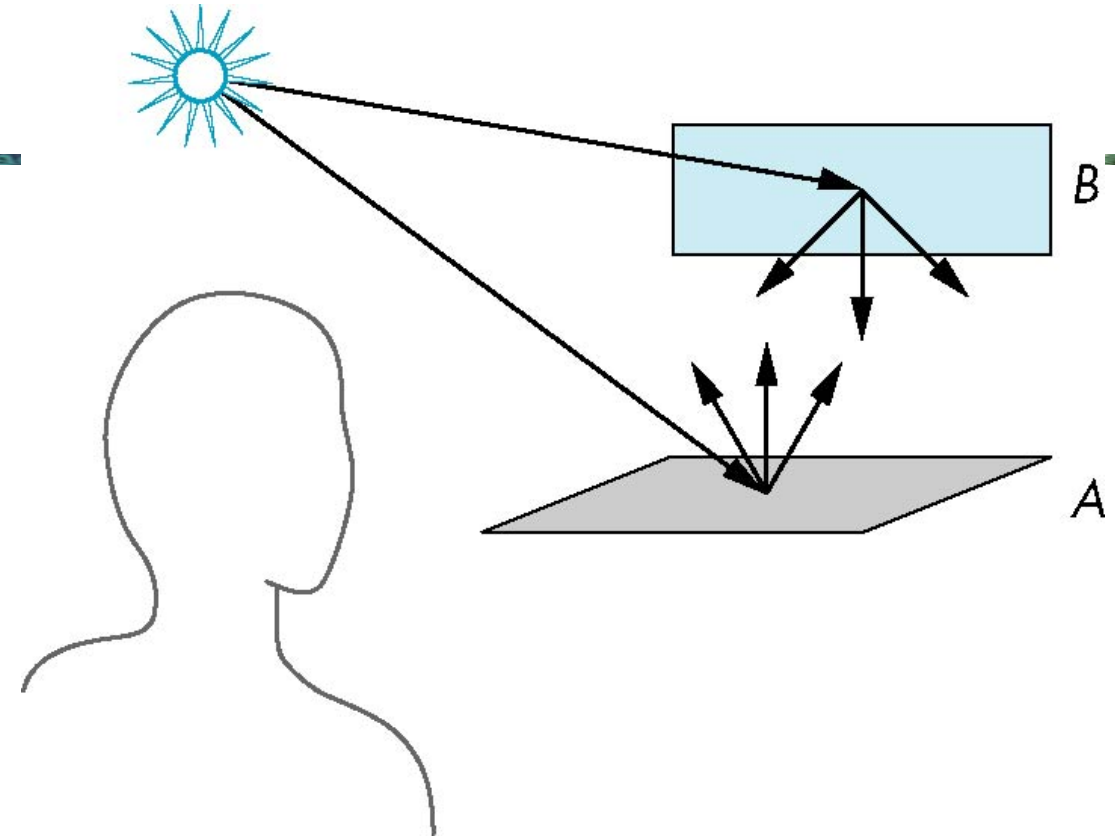
Shading refers to the process of determining the color for a pixel (or vertex...or polygon) during the rendering process



What is the difference between the two images?

Scattering

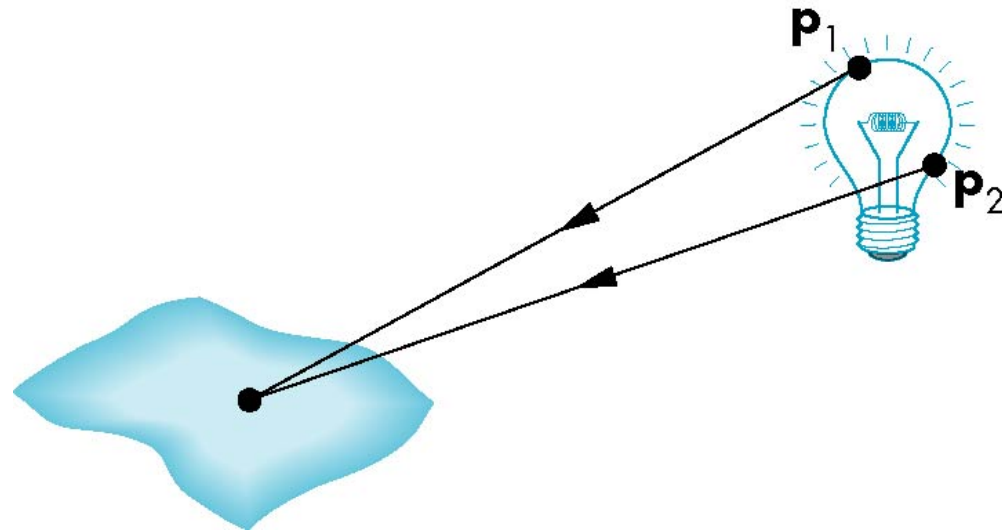
- Light strikes A
 - Some scattered
 - Some absorbed
- Some of scattered light strikes B
 - Some scattered
 - Some absorbed
- Some of this scattered light strikes A and so on



Light Sources

General light sources are complex to model

Would need to integrate light coming from all points on the source

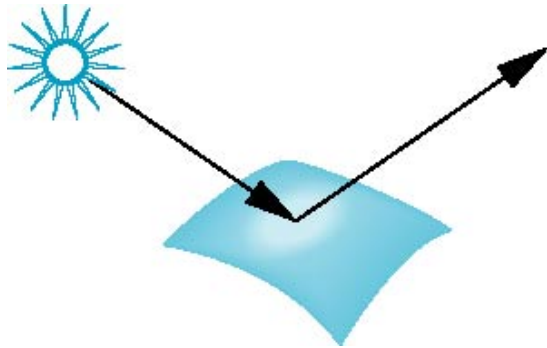


Simple Light Source Models

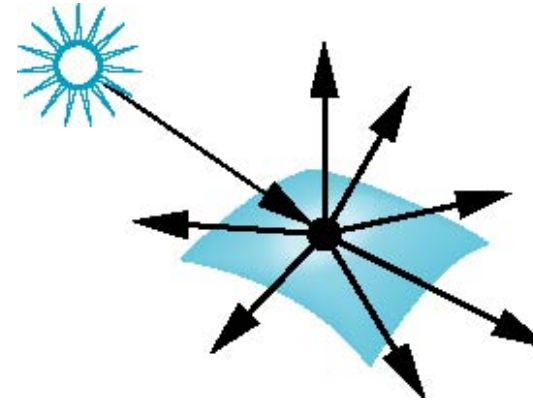
- Point source
 - Model with position and color
- Directional source
 - Distant source = infinite distance away (parallel)
- Ambient light
 - Same amount of light everywhere in scene
 - Can model contribution of many sources and reflecting surfaces

Surface Types

- Consider light traveling along a specific ray
- The smoother a surface, the more reflected light is concentrated in a single direction
 - Perfect mirror reflects perfectly in a single direction
- A very rough surface scatters light in all directions



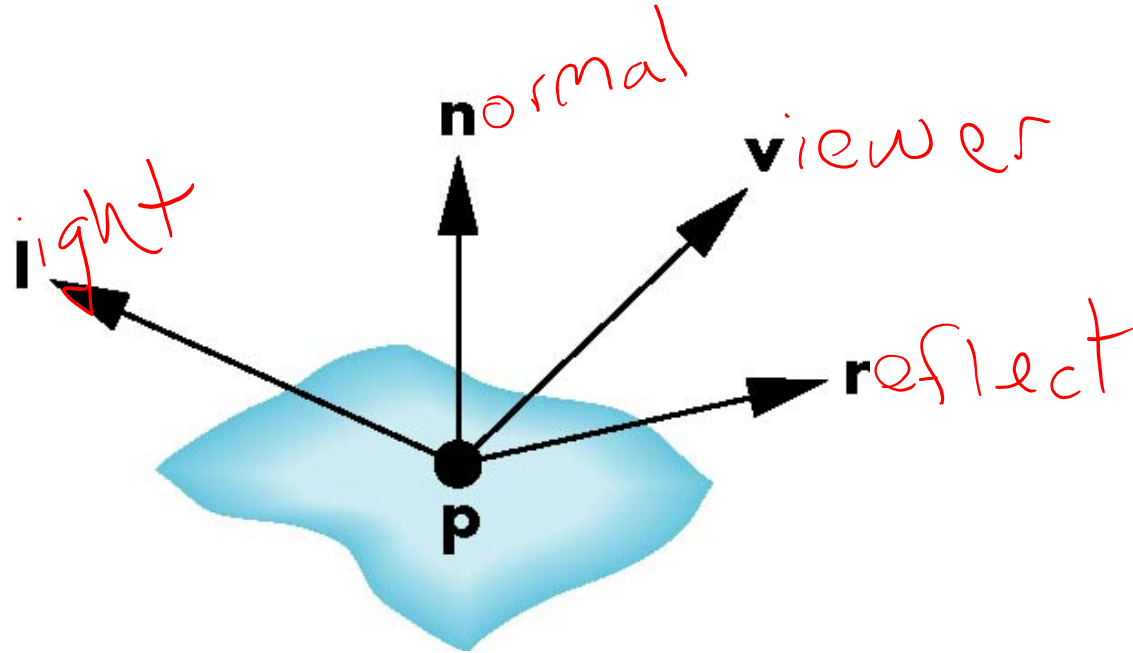
smooth surface



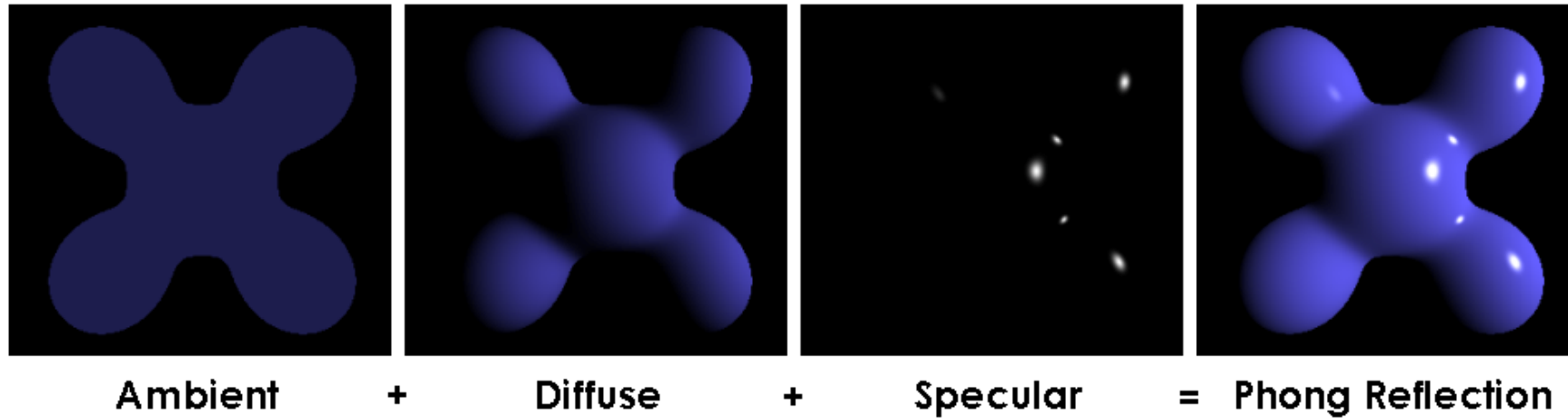
rough surface

The Phong Reflection Model

- A simple model that can be computed rapidly
- Has three components
 - Diffuse
 - Specular
 - Ambient
- Uses four vectors
 - To light
 - To viewer
 - Normal
 - Perfect reflector



Phong Reflectance Model

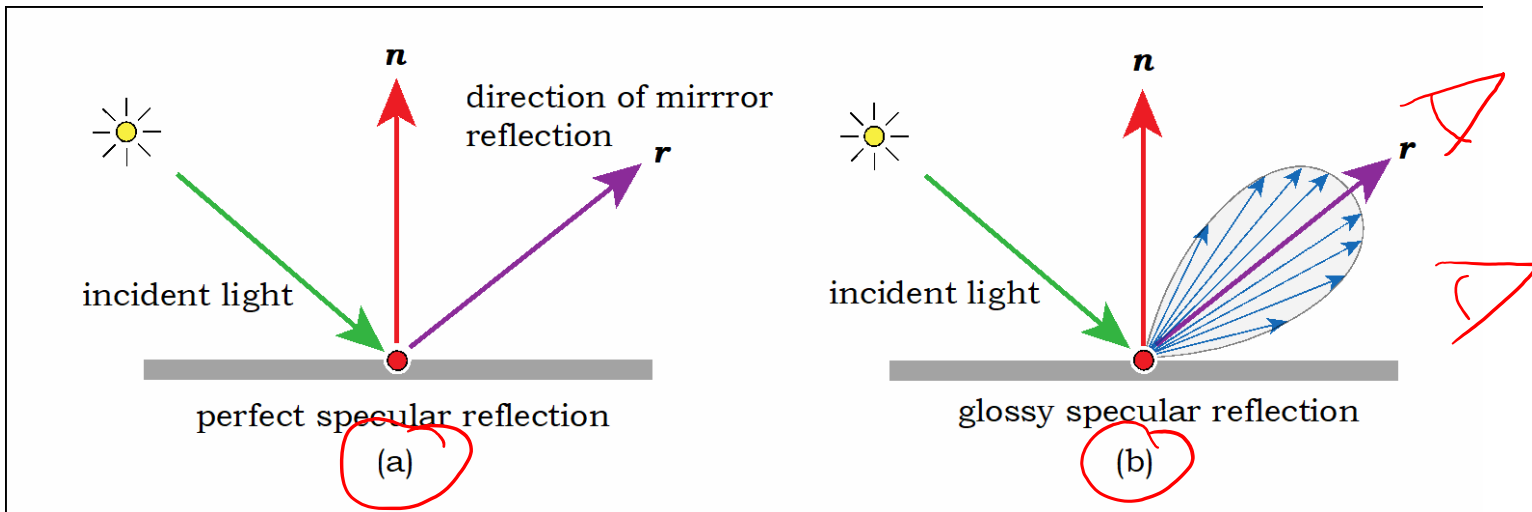
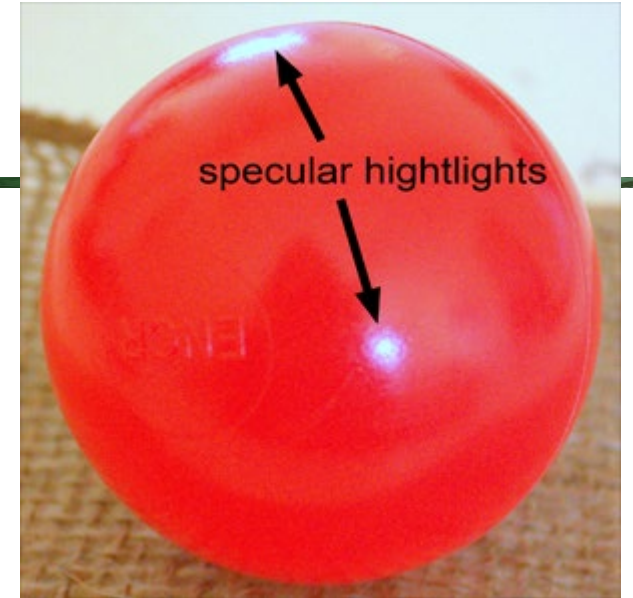


$$I_p = k_a i_a + \sum_{m \in \text{lights}} (k_d (\hat{L}_m \cdot \hat{N}) i_{m,d} + k_s (\hat{R}_m \cdot \hat{V})^\alpha i_{m,s})$$

$$(1, 0, 0) \cdot (1/4, 1/4, 1/4) = (1/4, 0, 0)$$

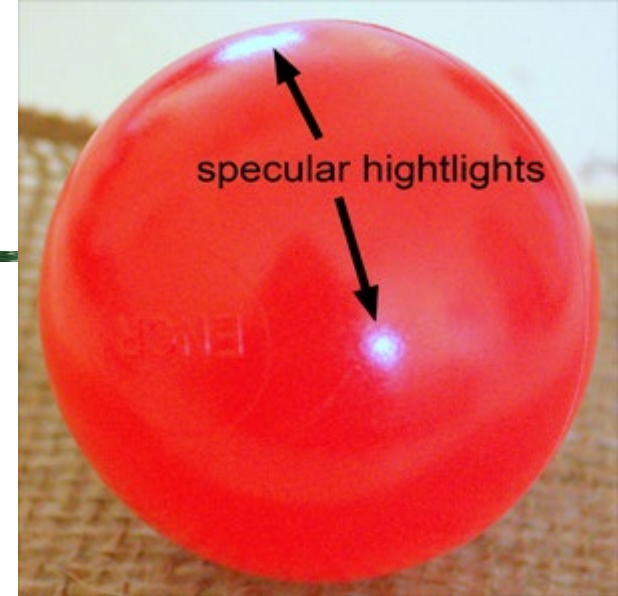
Specular Reflection

- Perfect specular reflection
 - Light is reflected in the single direction r
 - ...the mirror reflection direction
- Glossy specular reflection
 - Scattering clustered around mirror reflection direction



Specular Reflection

- Reflectance determined by
 - Alignment of view vector with mirror reflection vector
 - Shininess coefficient
- High coefficient means smoother look
 - Maybe 100 for metal
 - Maybe 10 for plastic



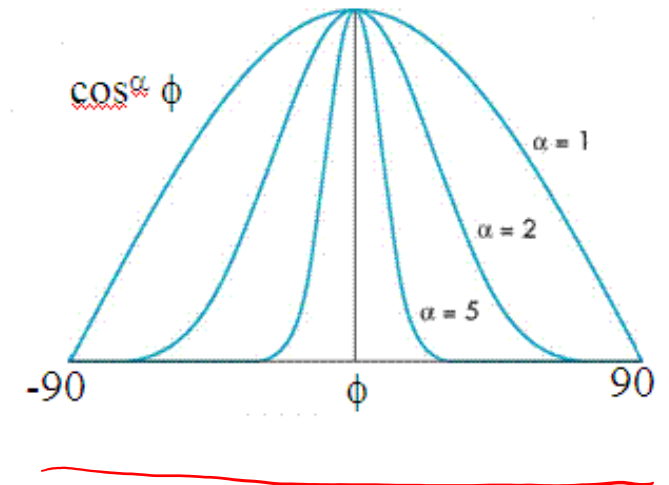
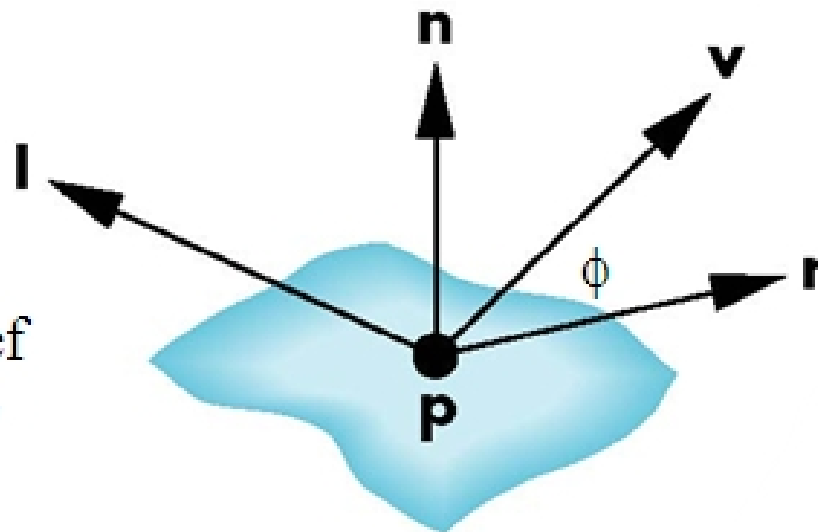
$$I_r \sim k_s I \cos^\alpha \phi$$

reflected intensity

shininess coef

incoming intensity

absorption coef

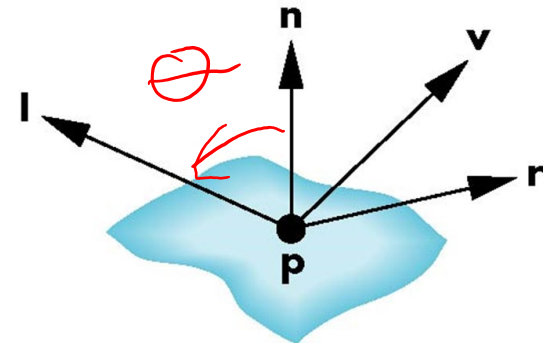
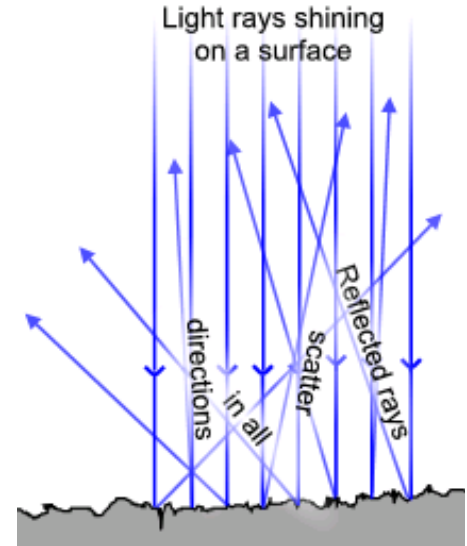


Modeling a Lambertian Surface – Diffuse Reflection

- Perfectly diffuse reflector
- Light scattered equally in all directions
- Amount of light reflected is affected by the angle of incidence
 - reflected light proportional to **cosine of angle between l and n**
 - if vectors normalized

$$\cos(\theta) = n \cdot l$$

- Amount of reflected light also affected by k_d and i_d
 - Each is an rgb value with each channel in $[0,1]$

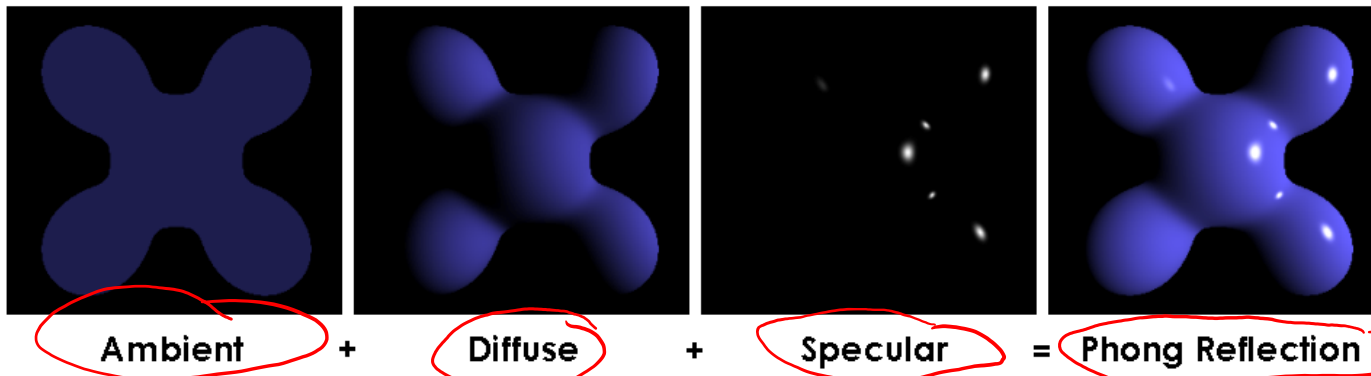


Ambient Light

- Result of multiple interactions between light sources and surfaces
- Amount and color depend on the color of the light(s) and the material properties

- Add $k_a I_a$ to diffuse and specular terms
reflection intensity of ambient light

Remember that k_i multiplications are component-wise multiplications of rgb values
 $(k_r, k_g, k_b)(i_r, i_g, i_b) = (k_r i_r, k_g i_g, k_b i_b)$

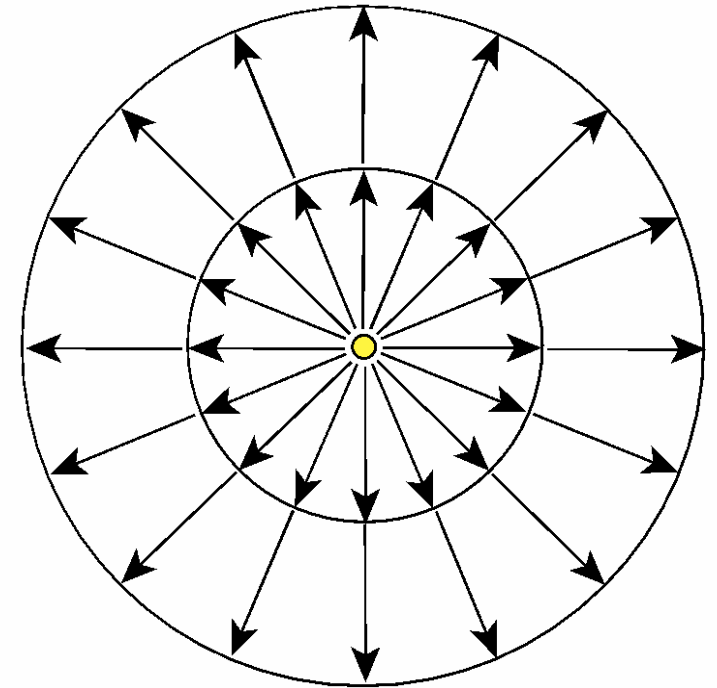


Distance Terms

- The light from a point source that reaches a surface is ***attenuated***
 - Intensity falls off with the square of the distance
- We can apply a factor to the diffuse and specular terms

$$\frac{1}{ad^2 + bd + c}$$

- **d** is the distance from the light to surface
- **a,b,c** are constants you choose to get different effects



Blinn-Phong Reflectance Model

- Jim Blinn suggested an approximating changing specular term
- Replace $(V \cdot R)^a$ by $(N \cdot H)^b$ where
 - “Halfway vector”
- More efficient in terms of the operations used
- Closer to physically correct lighting
- Pick exponent ***b*** to match what you want
 - Using higher ***b > a*** will make output similar to Phong with ***a***

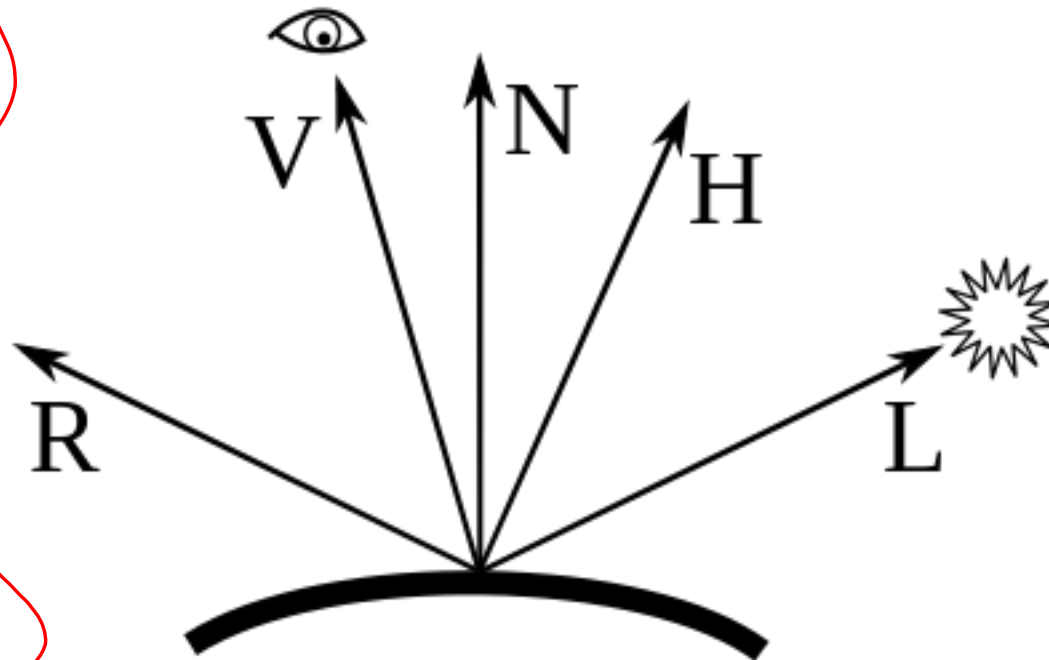
$$H = \frac{L + V}{\|L + V\|}$$

The Halfway Vector

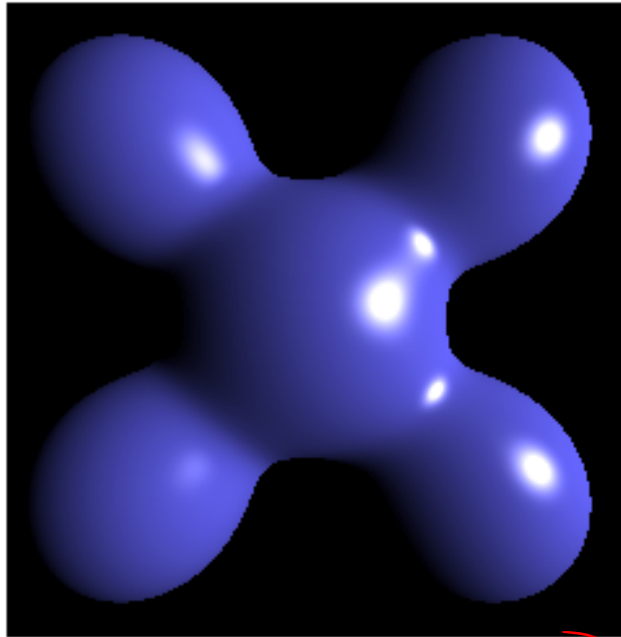
H is normalized vector halfway between **L** and **V**

$$H = \frac{L + V}{\|L + V\|}$$

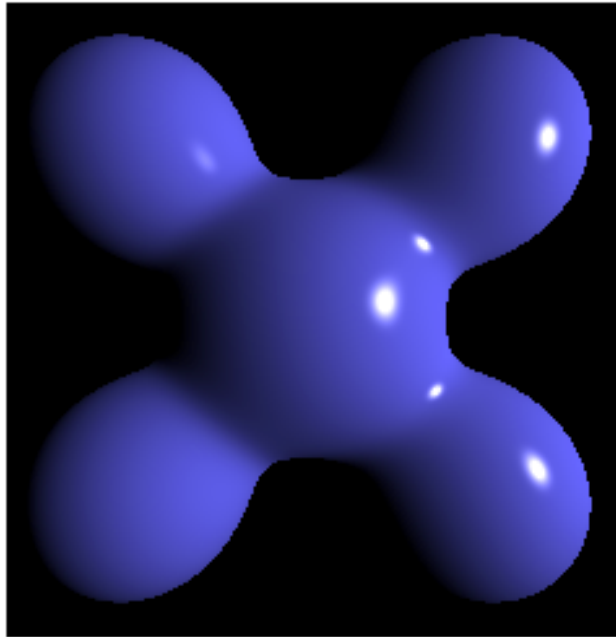
$$r = 2(l \cdot n)n - l$$



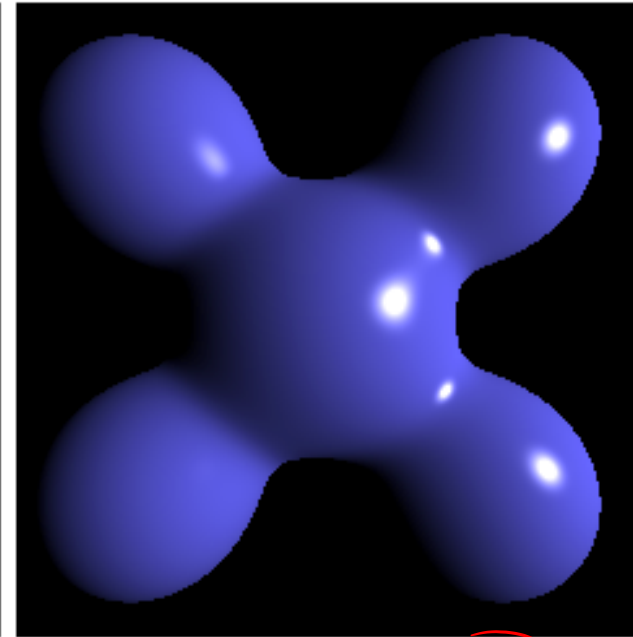
Phong versus Blinn-Phong



Blinn-Phong



Phong



Blinn-Phong
(higher exponent)

Gouraud and Phong Shading

- **Gouraud Shading**

- Find average normal at each vertex
- Compute shade at each vertex
- Interpolate vertex shades across each polygon

- **Phong shading**

- Find average normal at each vertex
- Interpolate vertex normals across edges
- Interpolate edge normals across polygon
- Compute shade at each fragment



Phong Shading is NOT THE SAME as the Phong reflectance model

Bui Tuong Phong

- December 14, 1942 – July 1975
- Born in Hanoi
- Earned his PhD in 2 years at the University of Utah (1973)
 - Worked with Professor Ivan Sutherland
 - Dissertation work was the Phong reflectance model
 - Also produced model and realistic image of a VW bug

Graphics and
Image Processing

W. Newman
Editor

Illumination for Computer Generated Pictures

Bui Tuong Phong
University of Utah

Fig. 9. Improved shading, applied to the example of Figure 2.

