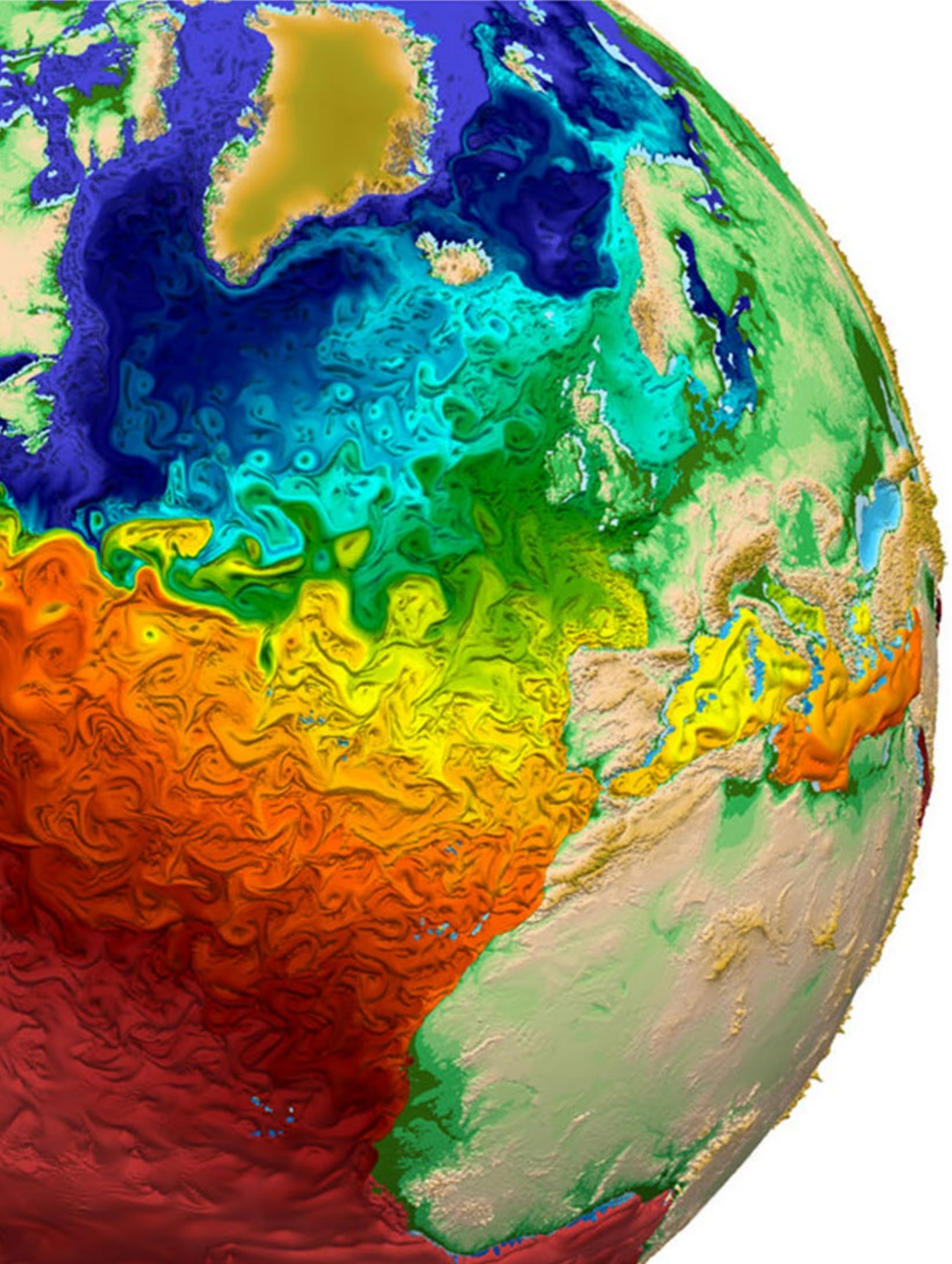

# 3D Computer Graphics for People in a Hurry

## Shading

Professor Eric Shaffer

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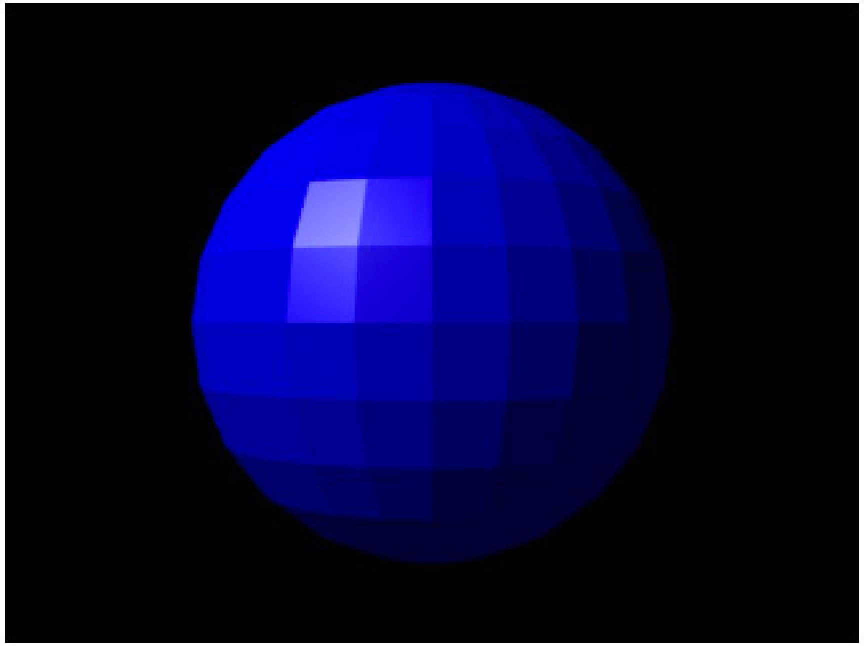
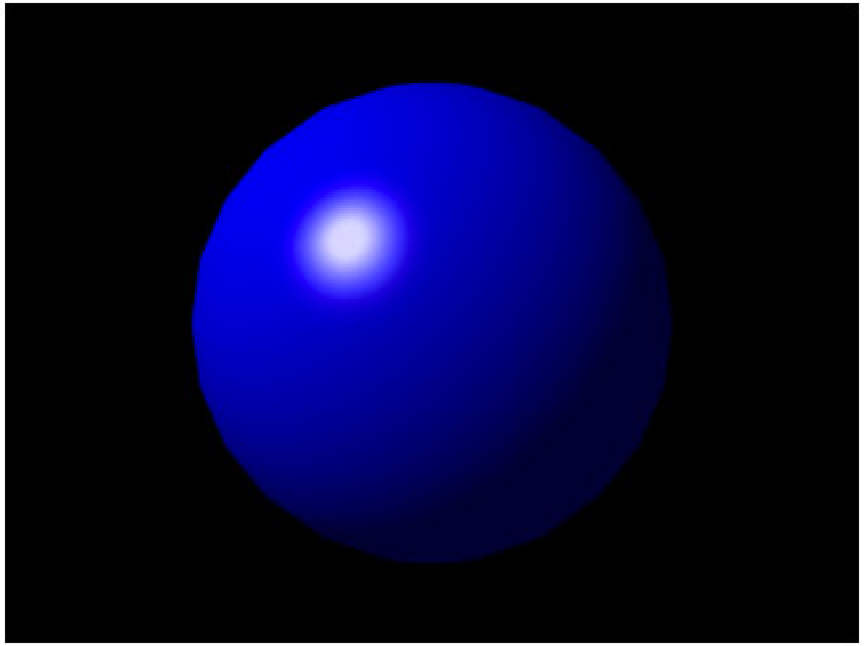
# Shading

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

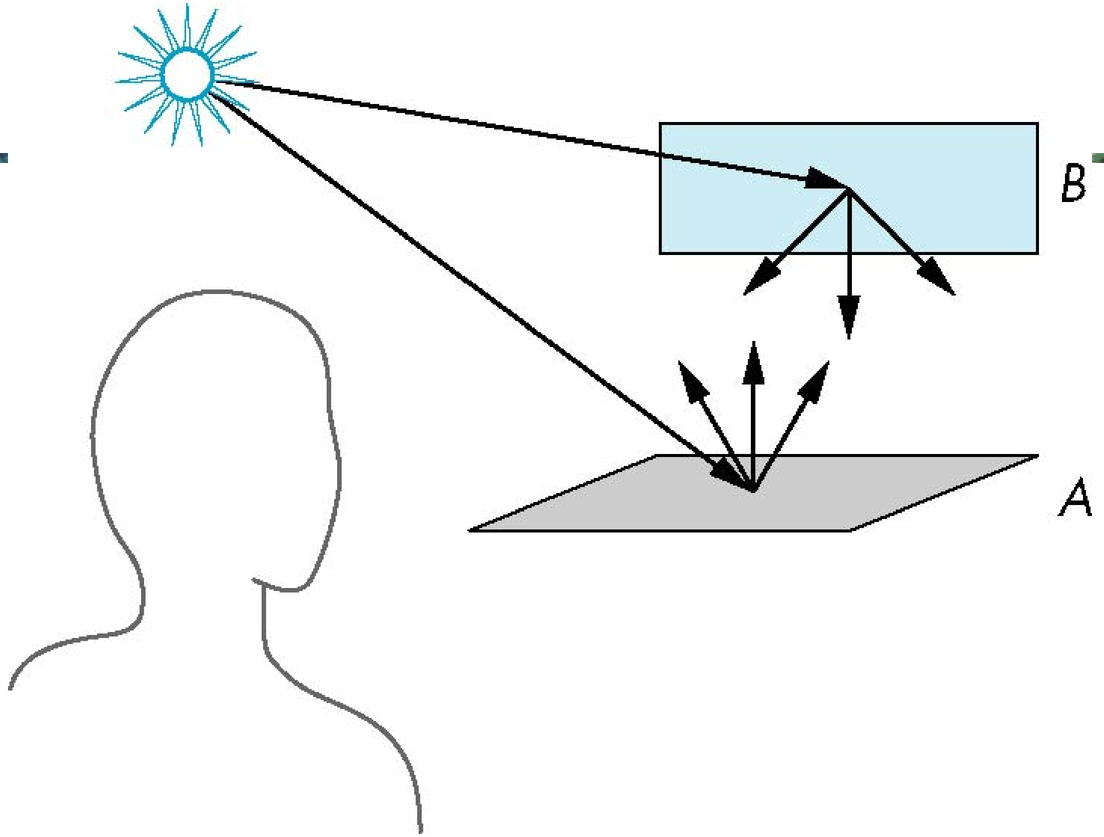




What is the difference between the two images?

# Scattering

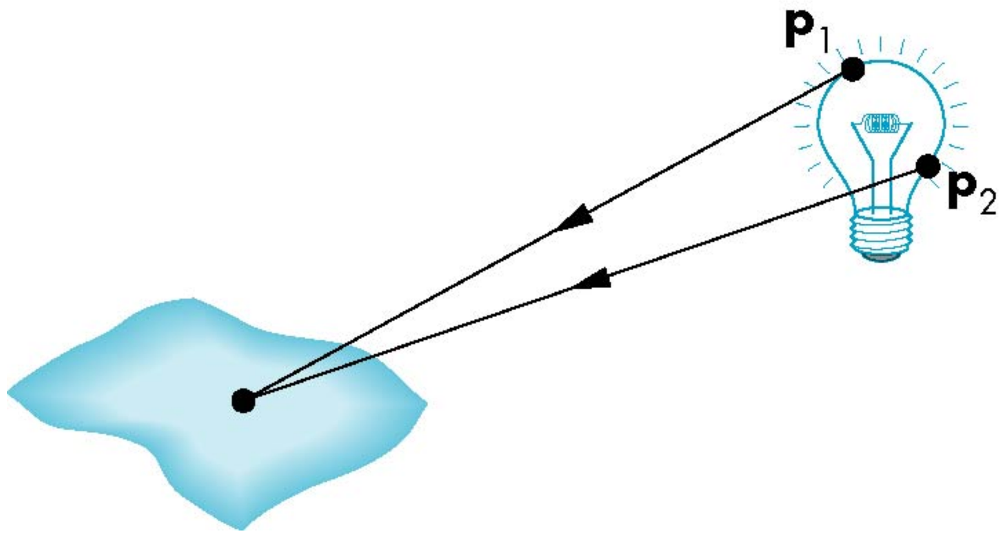
- Light strikes A
  - Some scattered
  - Some absorbed
- Some of scattered light strikes B
  - Some scattered
  - Some absorbed
- Some of this scattered light strikes A and so on



# Light Sources

General light sources are complex to model

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

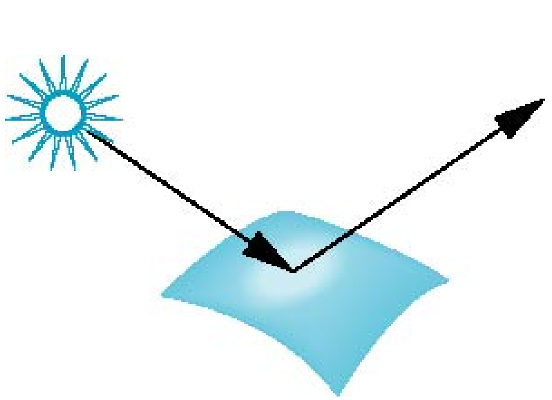


# Simple Light Source Models

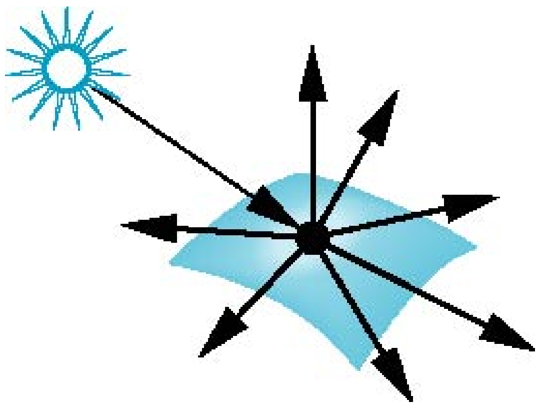
- Point source
  - Model with position and color
- Directional source
  - Distant source = infinite distance away (parallel)
- Ambient light
  - Same amount of light everywhere in scene
  - Can model contribution of many sources and reflecting surfaces

# 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



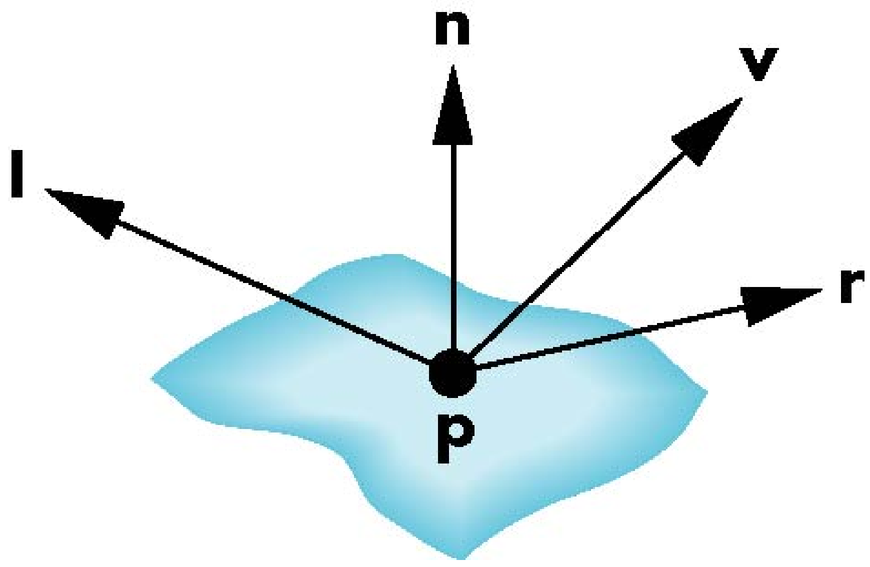
smooth surface



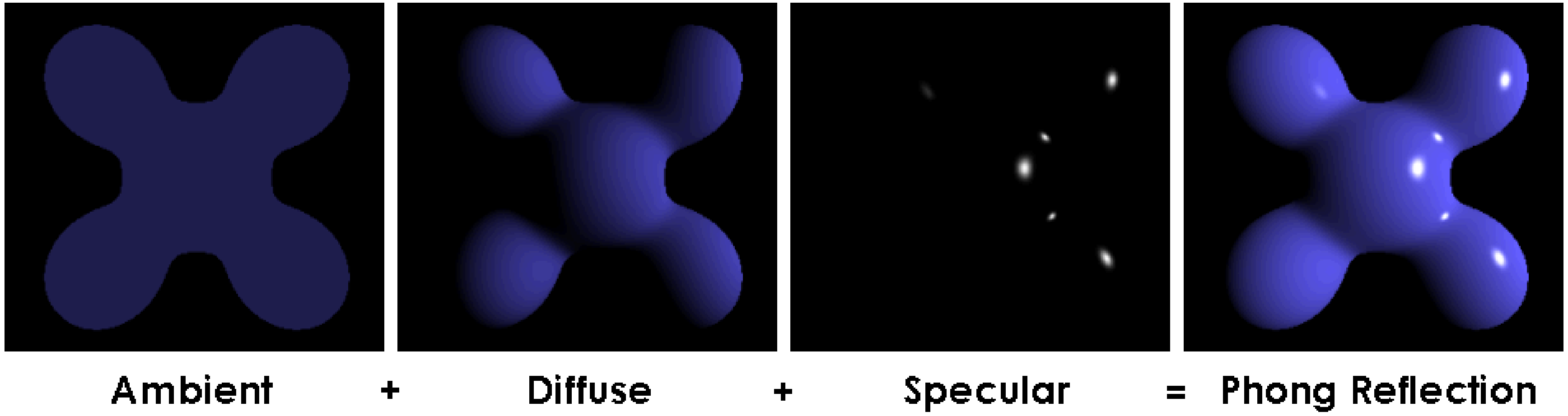
rough surface

# 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




$$I_{\mathrm{p}} = k_{\mathrm{a}} i_{\mathrm{a}} + \sum_{m \in \text{lights}} \left( k_{\mathrm{d}} (\hat{L}_m \cdot \hat{N}) i_{m,\mathrm{d}} + k_{\mathrm{s}} (\hat{R}_m \cdot \hat{V})^{\alpha} i_{m,\mathrm{s}} \right)$$

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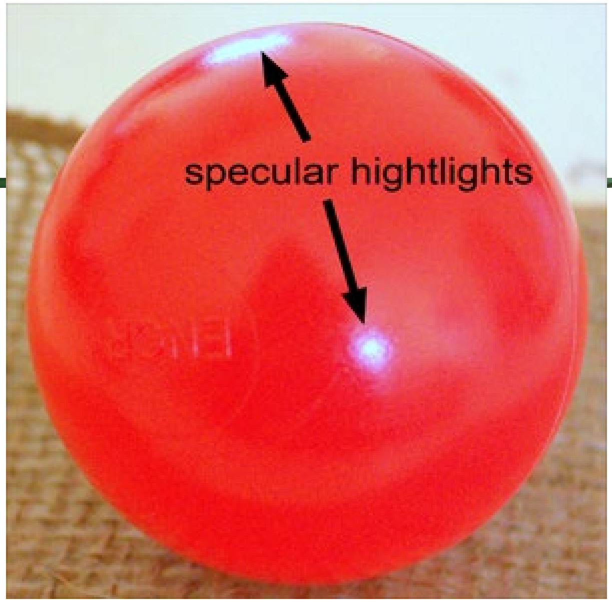
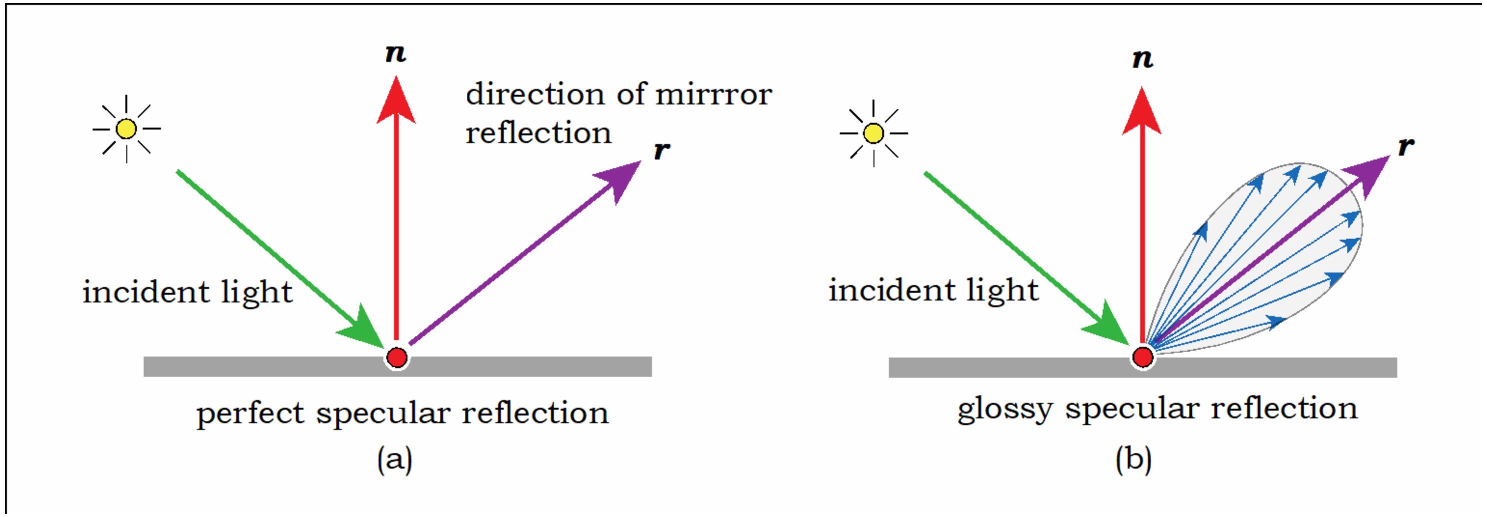
# Specular Reflection




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

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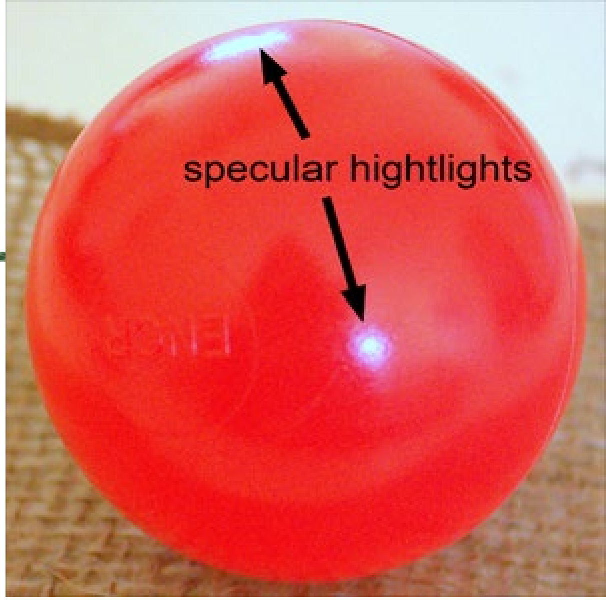
# Specular Reflection




- 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

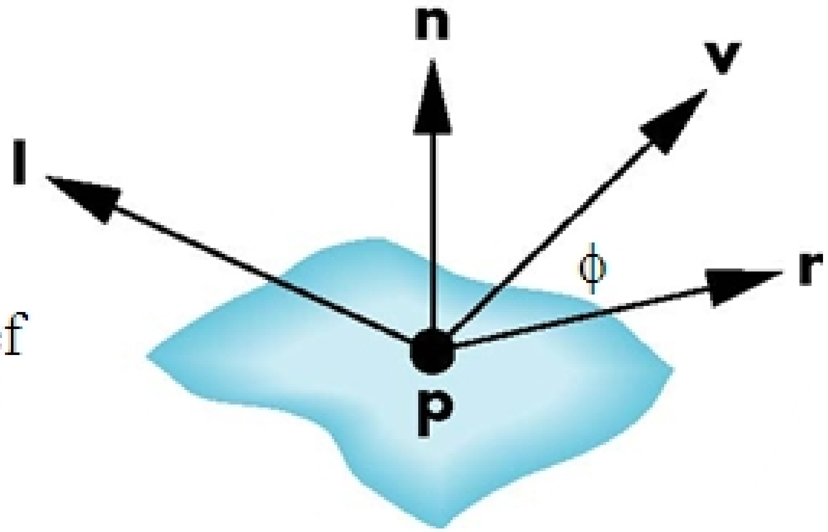
$$I_r \sim k_s \, I \cos^{\alpha}\phi$$

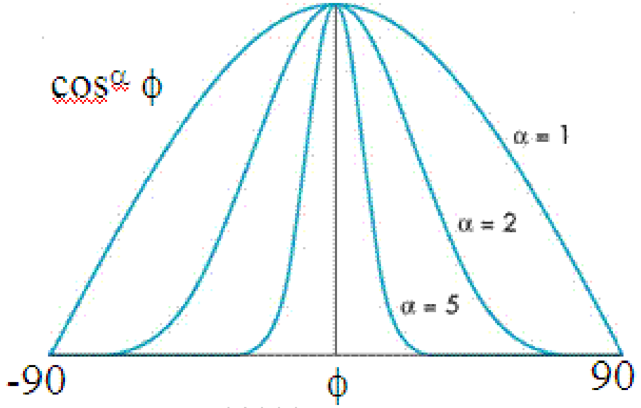
reflected intensity

absorption coef

incoming intensity

shininess coef

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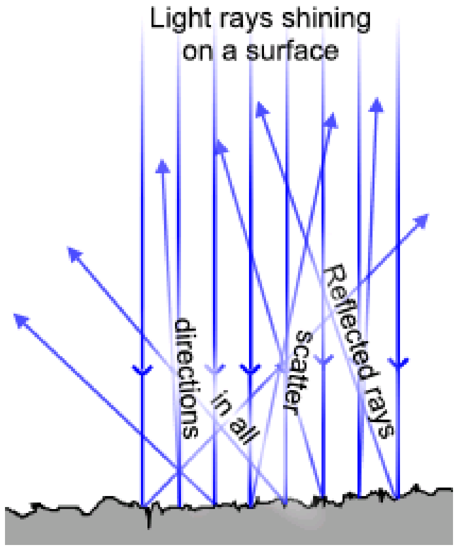
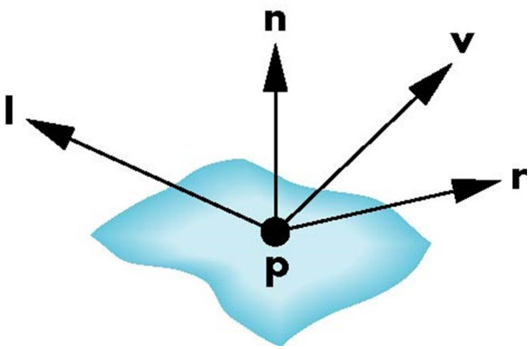
# Modeling a Lambertian Surface – Diffuse Reflection

- 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]

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# Ambient Light

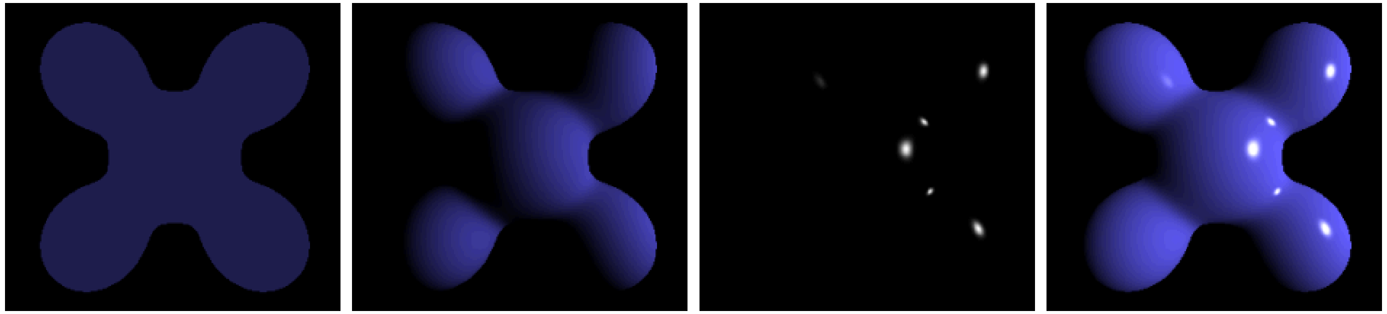
- Result of multiple interactions between light sources and surfaces

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



Ambient + Diffuse + Specular = Phong Reflection

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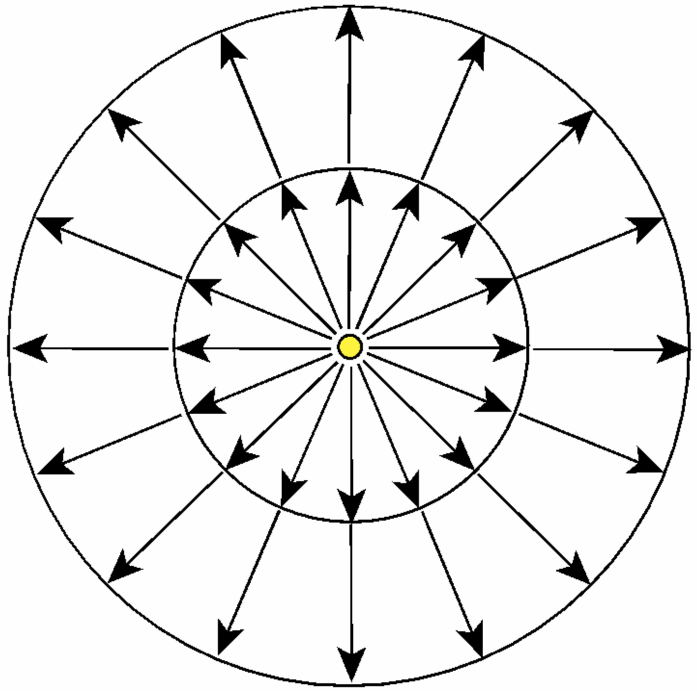
# Distance Terms

- 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 $(\mathbf{V} \cdot \mathbf{R})^a$ by $(\mathbf{N} \cdot \mathbf{H})^b$ where
  - "Halfway vector"

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

- 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***

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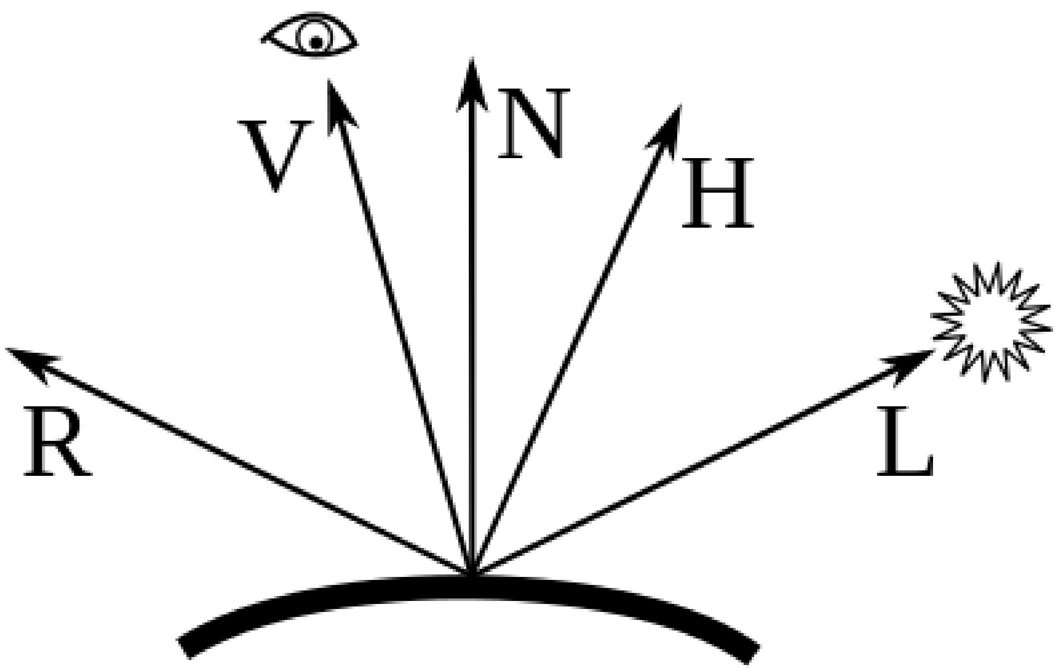
# The Halfway Vector

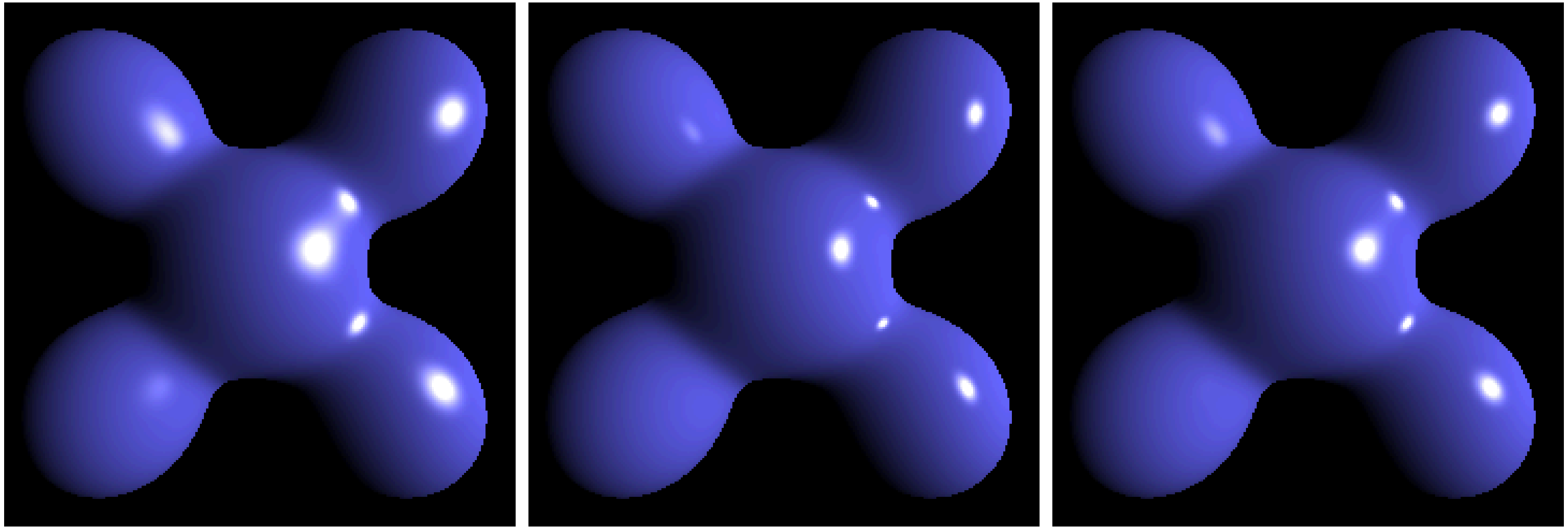
**H** is normalized vector halfway between **L** and **V**

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

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



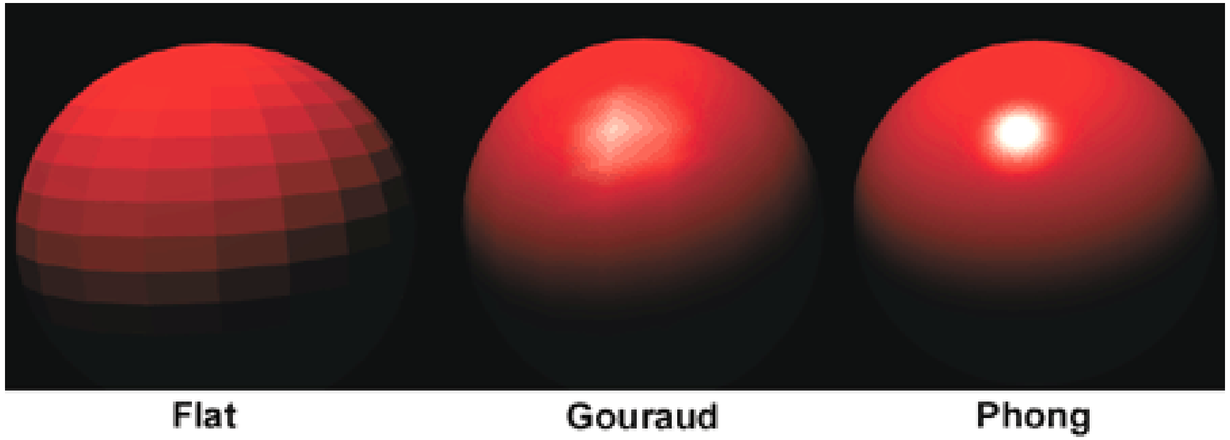
# Phong versus Blinn-Phong



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.