Shading

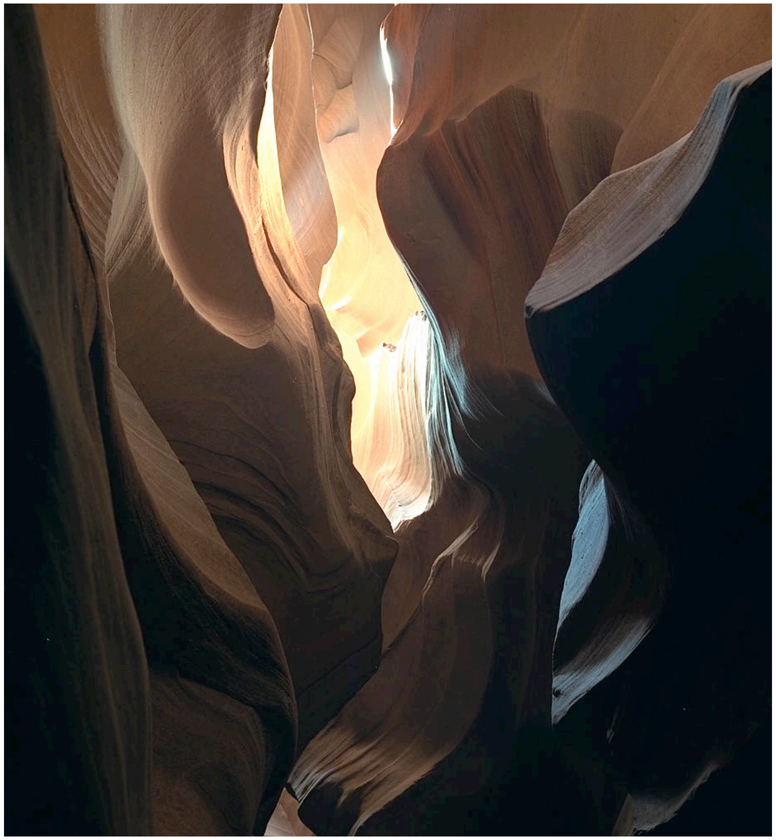
CS 465 Lecture 4

Visual cues to 3D geometry

- size (perspective)
- occlusion
- shading

Shading

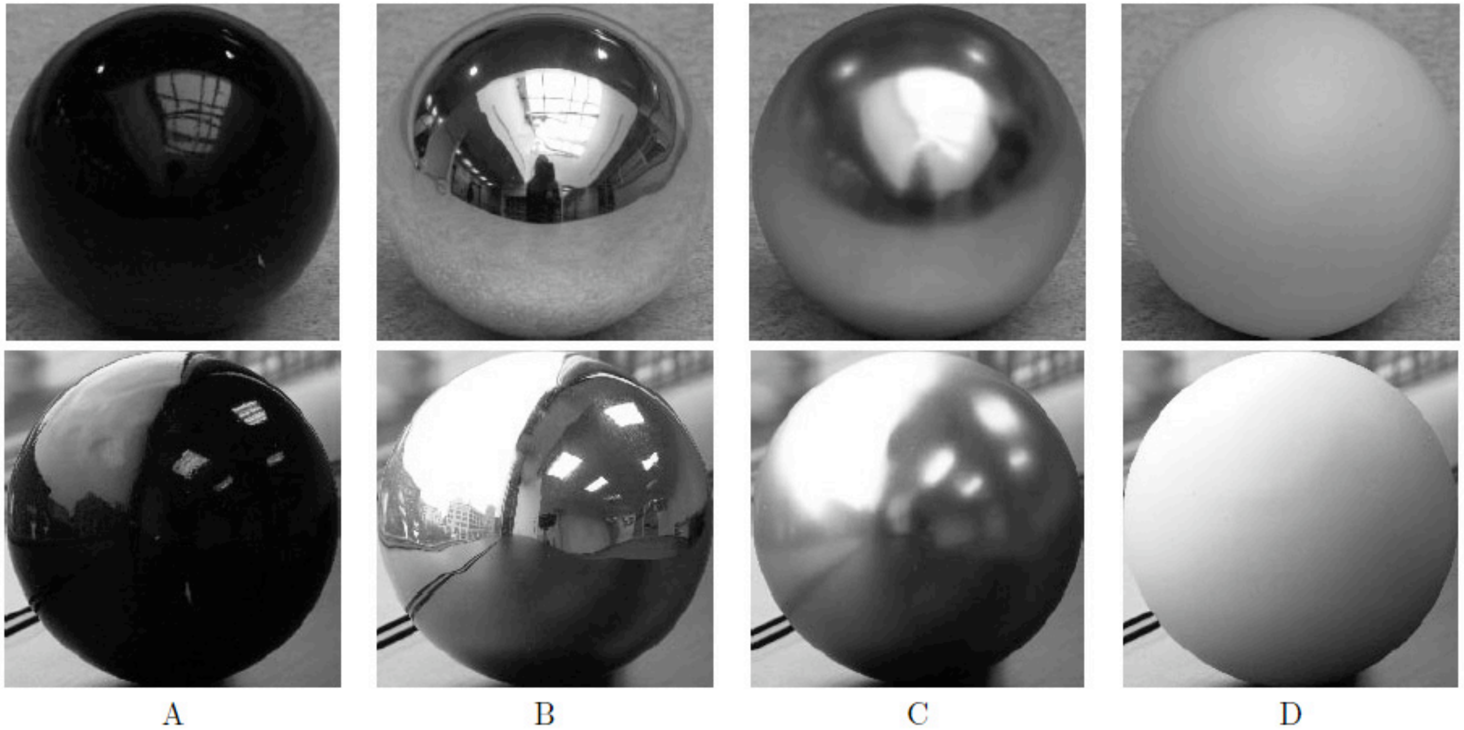
- Variation in observed color across an object
  - strongly affected by lighting
  - present even for homogeneous material
- caused by how a material reflects light
  - depends on
    - geometry
    - lighting
    - material
  - therefore gives cues to all 3



[Philip Greenspun]

Recognizing materials

- Human visual system is quite good at understanding shading



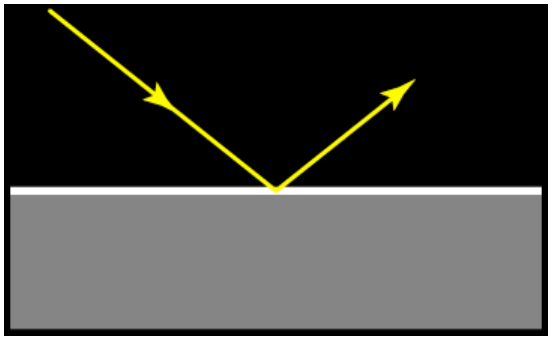
[Dror, Adelson, & Willsky]

Shading for Computer Graphics

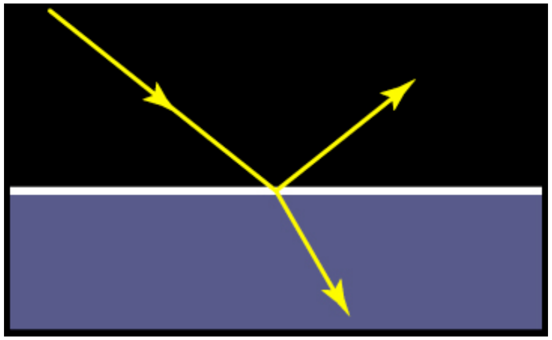
- Need to compute an image
  - of particular geometry
  - under particular illumination
  - from a particular viewpoint
- Basic question: how much light reflects from an object toward the viewer?

Simple materials

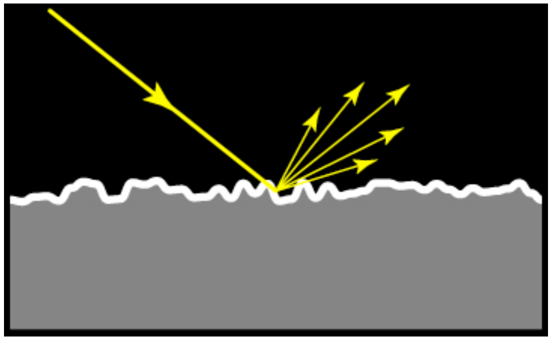
metal

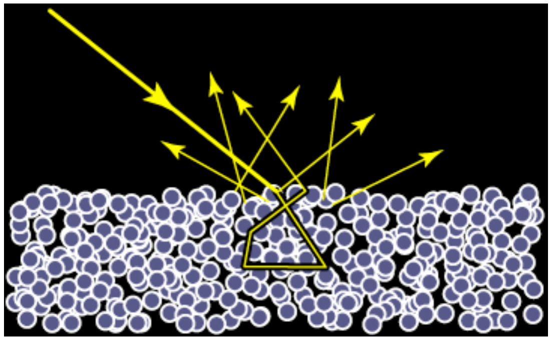


dielectric

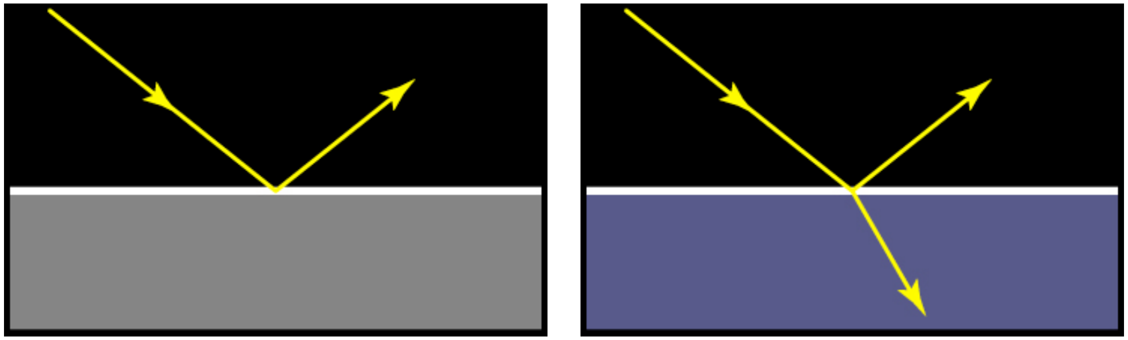


Adding microgeometry

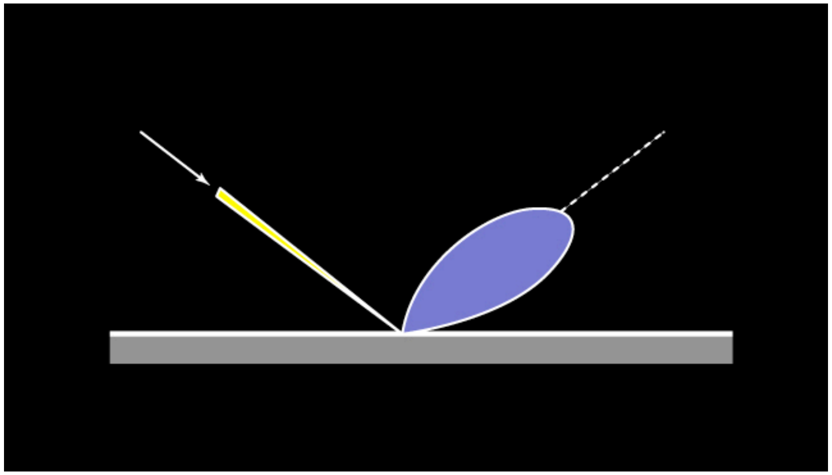




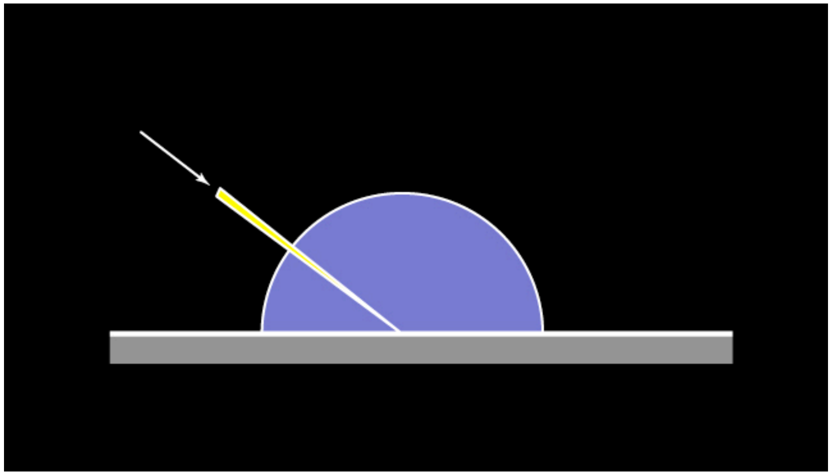
Classic reflection behavior



ideal specular (Fresnel)



rough specular



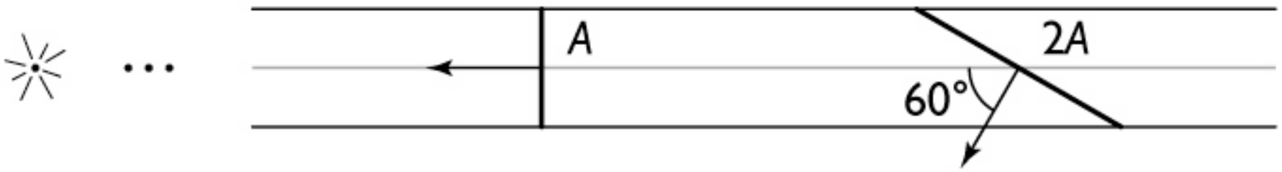
Lambertian

Basics of local lighting

- Diffuse reflection
  - light goes everywhere
  - colored by object color
- Specular reflection
  - happens only near mirror configurations
  - needs to be spread out some for point lights
  - usually white (except colored metals: e.g. copper, gold)
- Ambient reflection
  - don’t worry about where light comes from
  - just add a constant amount of light to account for other sources of illumination

Shading: diffuse reflection

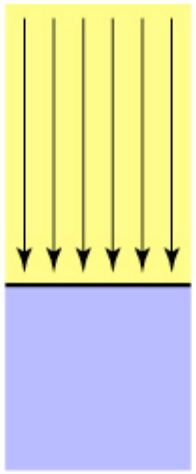
- Assume light reflects equally in all directions
  - therefore surface looks same color from all views: "view independent"
- Illumination on an oblique surface is less than on a normal one



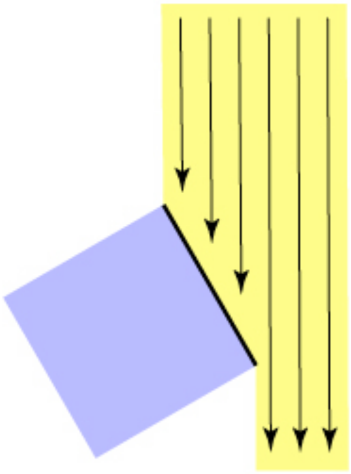
  - generally: illumination falls off as cos θ

Diffuse reflection

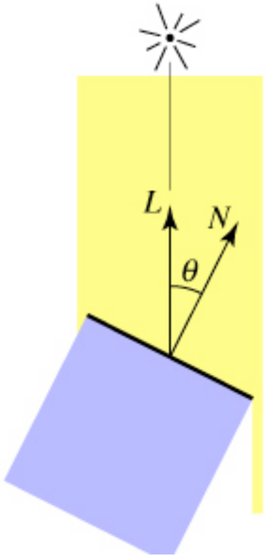
- Light is scattered uniformly in all directions
  - the surface color is the same for all viewing directions
- Lambert's cosine law



Top face of cube receives a certain amount of light



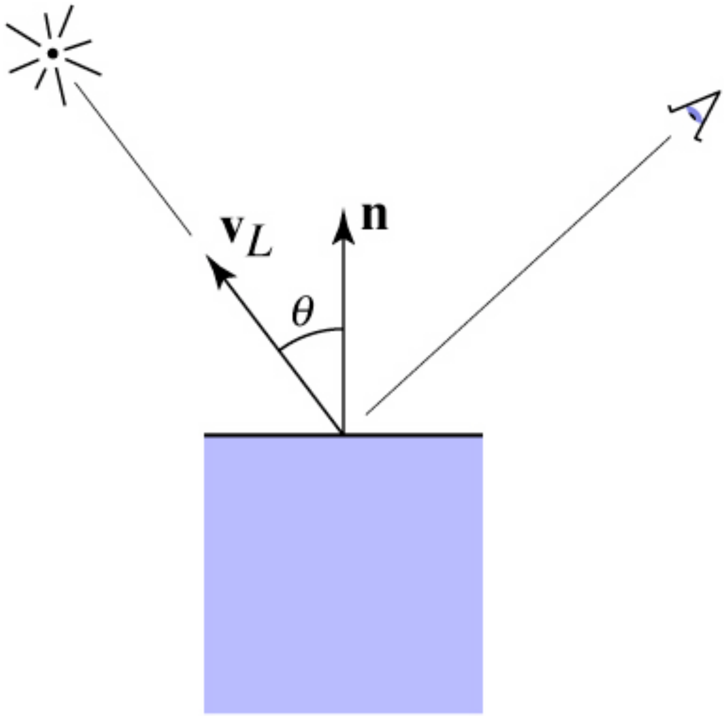
Top face of 60° rotated cube intercepts half the light



In general, light per unit area is proportional to $\cos\theta = L \cdot N$

Lambertian shading

- Shading independent of view direction



illumination from source

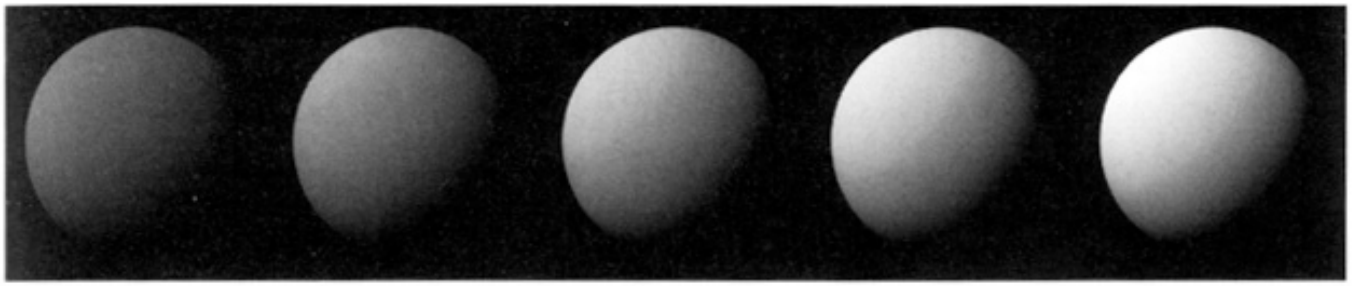
$$L_d = k_d\, I\, \max(0, \mathbf{n} \cdot \mathbf{v}_L)$$

diffuse coefficient

diffusely reflected light

Lambertian shading

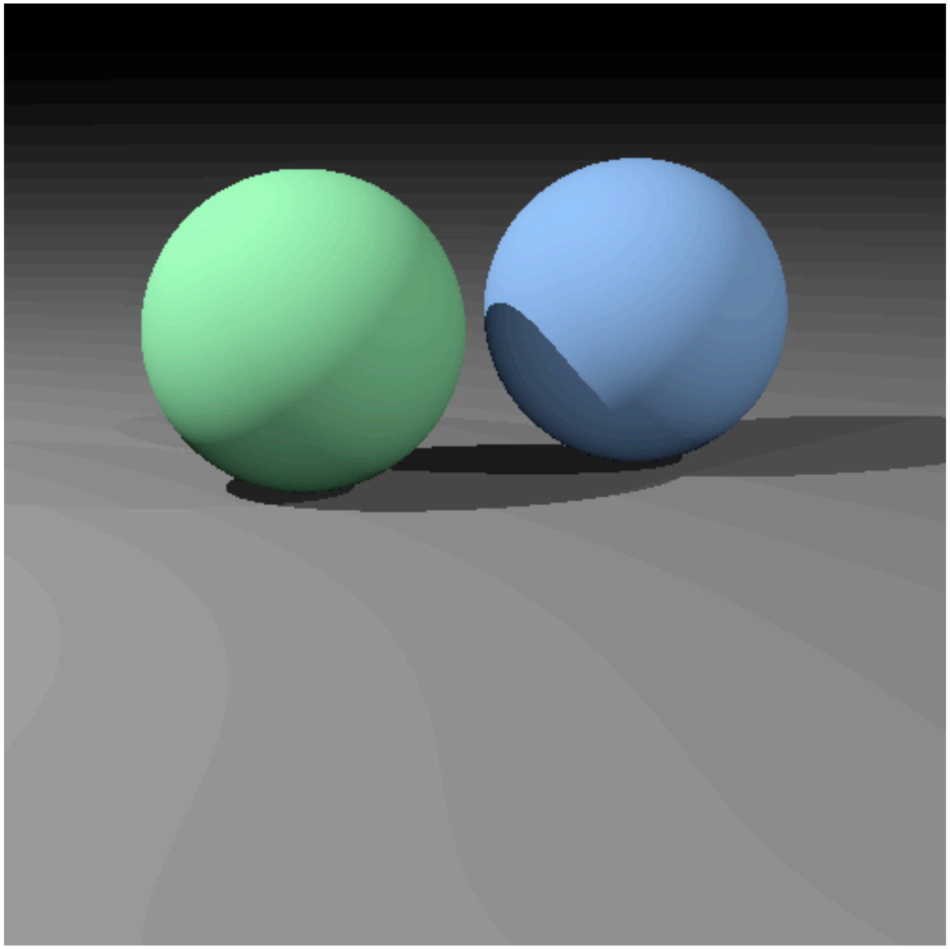
- Produces matte appearance



$k_D \longrightarrow$

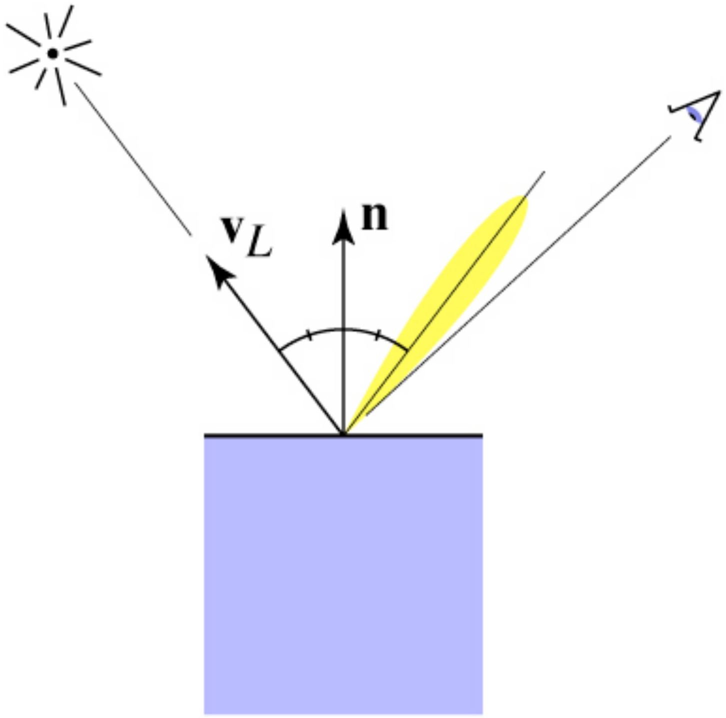
[Foley et al.]

Diffuse shading



Specular shading (Phong model)

- Intensity depends on view direction
  - bright near mirror configuration



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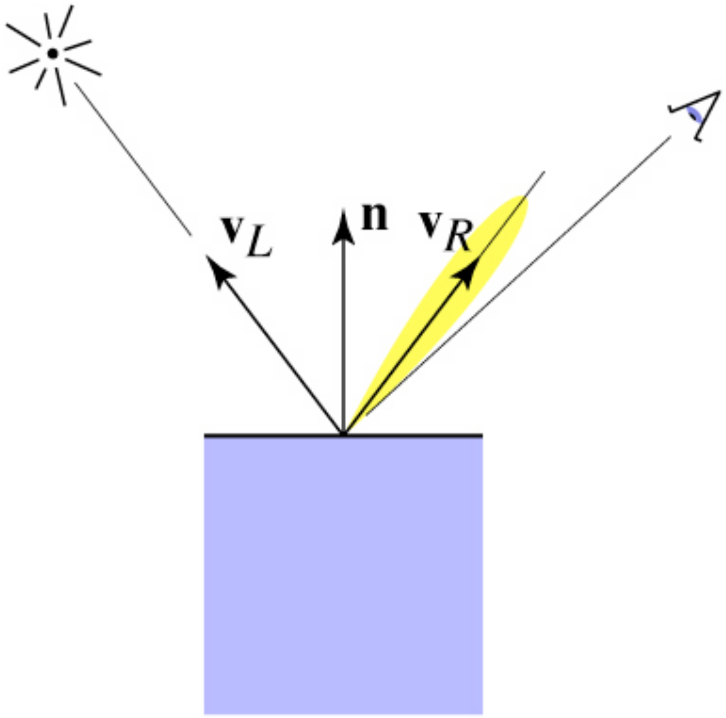

$$\begin{aligned}\mathbf{v}_R &= \mathbf{v}_L + 2((\mathbf{n}\cdot\mathbf{v}_L)\mathbf{n} - \mathbf{v}_L) \\ &= 2(\mathbf{n}\cdot\mathbf{v}_L)\mathbf{n} - \mathbf{v}_L\end{aligned}$$

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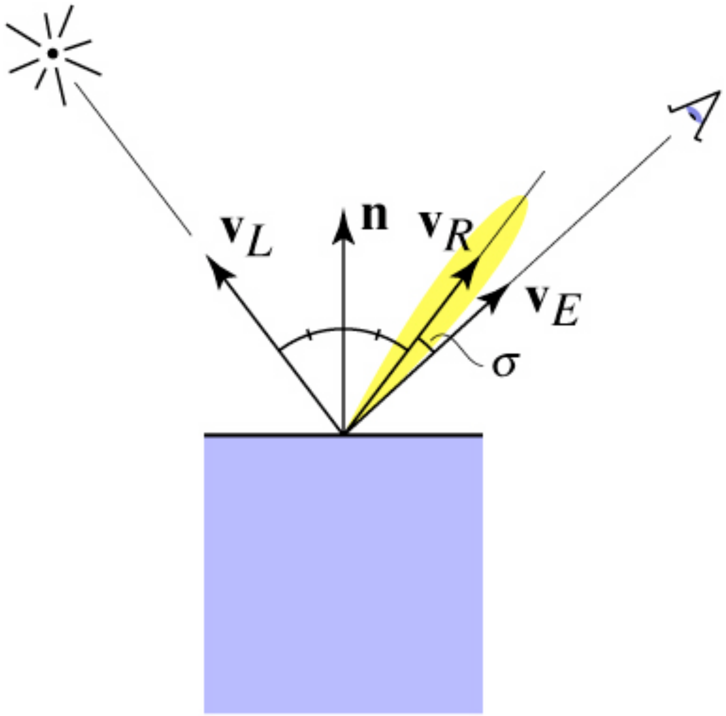

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$$\begin{aligned}L_s &= k_s\, I \max(0, \cos\sigma)^n \\ &= k_s\, I \max(0, \mathbf{v}_E \cdot \mathbf{v}_R)^n\end{aligned}$$

specularly reflected light

specular coefficient

Phong model—plots

- Increasing *n* narrows the lobe

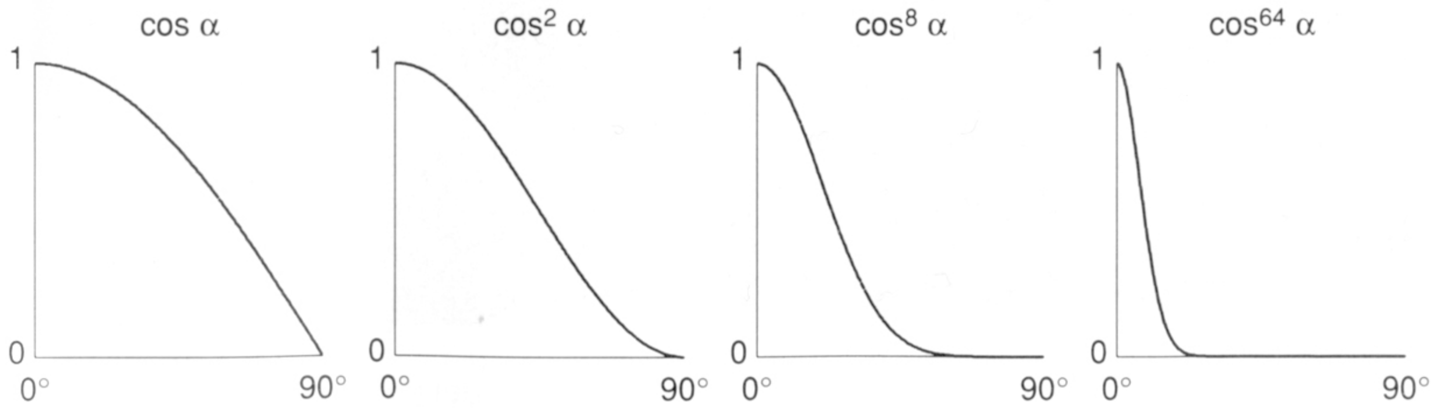
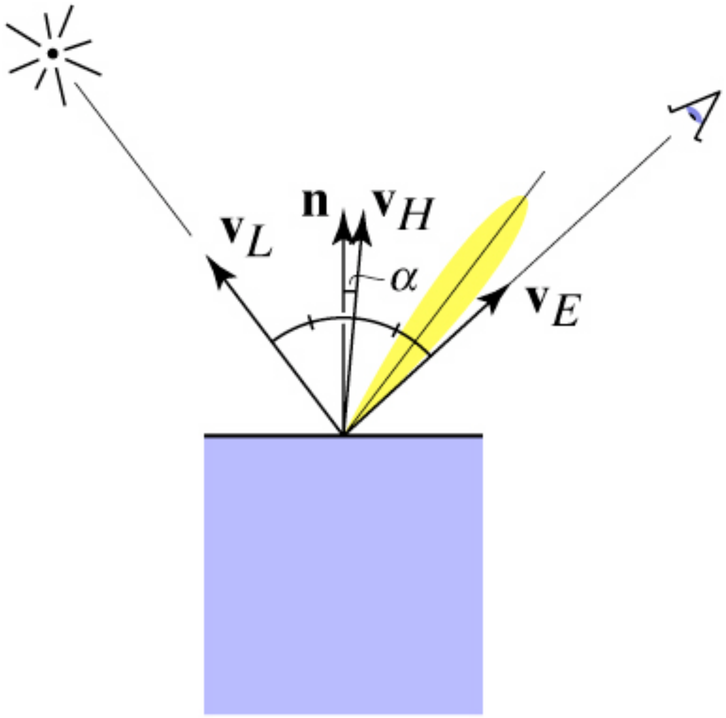


Fig. 16.9 Different values of $\cos^n \alpha$ used in the Phong illumination model.

[Foley et al.]

Phong variant: Blinn-Phong

- Rather than computing reflection directly, just compare to normal bisection property

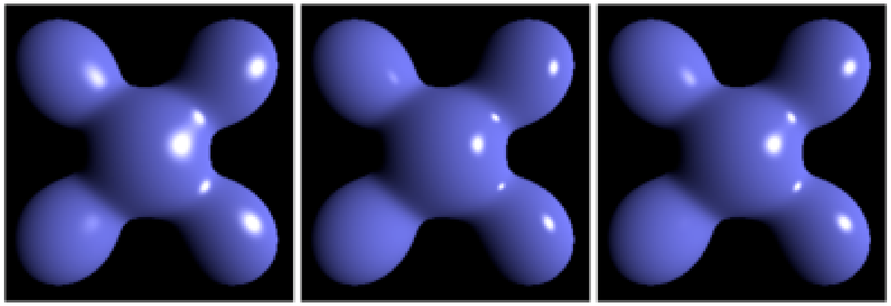


$$\mathbf{v}_H = \text{bisector}(\mathbf{v}_L, \mathbf{v}_E)$$
$$= \frac{(\mathbf{v}_L + \mathbf{v}_E)}{\|\mathbf{v}_L + \mathbf{v}_E\|}$$

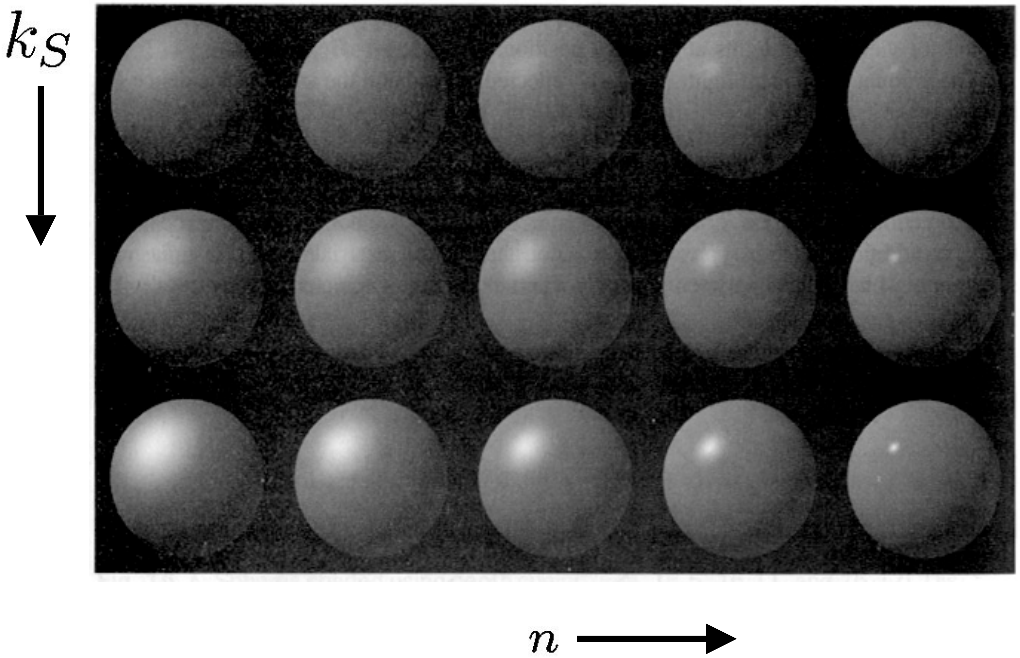
$$L_s = k_s\, I \max(0, \cos\alpha)^n$$
$$= k_s\, I \max(0, \mathbf{n} \cdot \mathbf{v}_H)^n$$

Specular shading

- Phong and Blinn-Phong

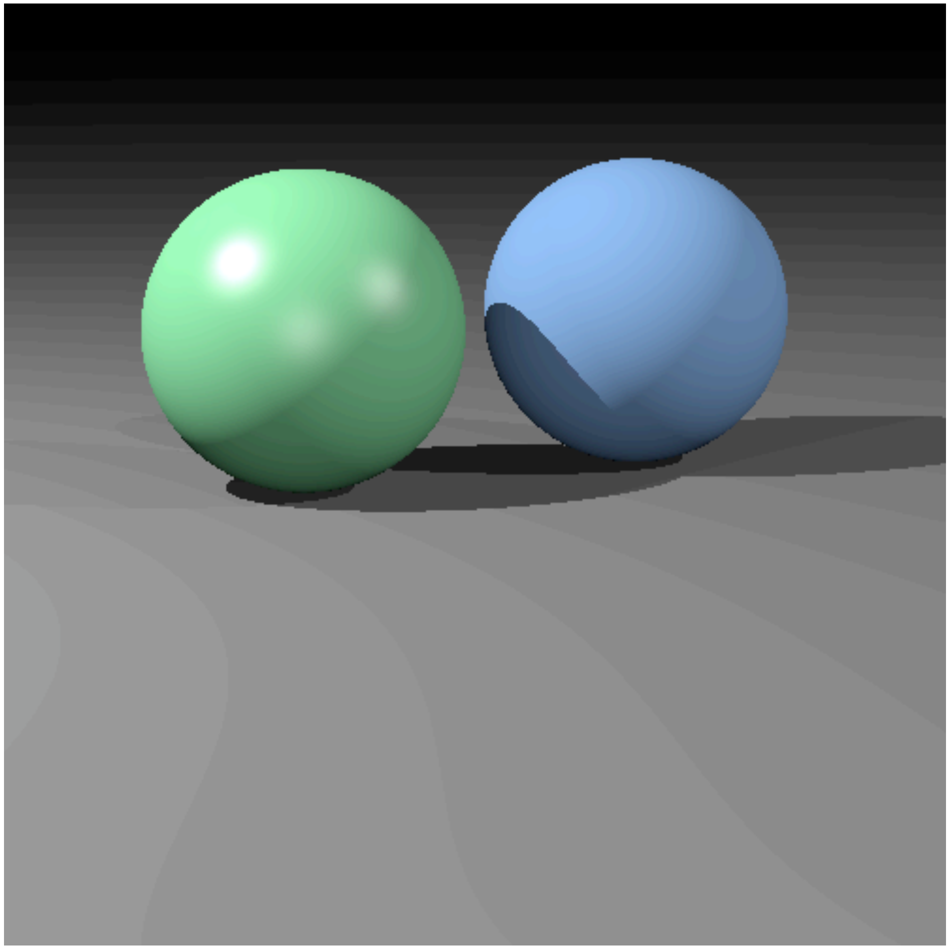


Blinn-Phong Phong Blinn-Phong (Lower Exponent)



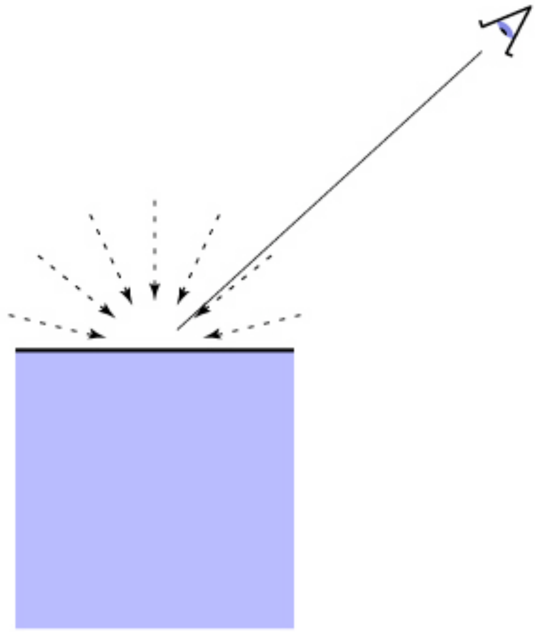
[Foley et al.]

Diffuse + Phong shading



Ambient shading

- Shading does not depend on anything
  - add constant color to account for disregarded illumination and fill in black shadows



$$L_a = k_a I_a$$

ambient coefficient

reflected ambient light

Putting it together

- Usually include ambient, diffuse, Phong in one model

$$\begin{aligned} L &= L_a + L_d + L_s \\ &= k_a I_a + I \left(k_d \max(0, \mathbf{n} \cdot \mathbf{v}_L) + k_s \max(0, \mathbf{n} \cdot \mathbf{v}_H)^n \right) \end{aligned}$$

- The final result is the sum over many lights

$$\begin{aligned} L &= L_a + \sum_i (L_d)_i + (L_s)_i \\ &= k_a I_a + \sum_i I_i \left(k_d \max(0, \mathbf{n} \cdot (\mathbf{v}_L)_i) + k_s \max(0, \mathbf{n} \cdot (\mathbf{v}_H)_i)^n \right) \end{aligned}$$

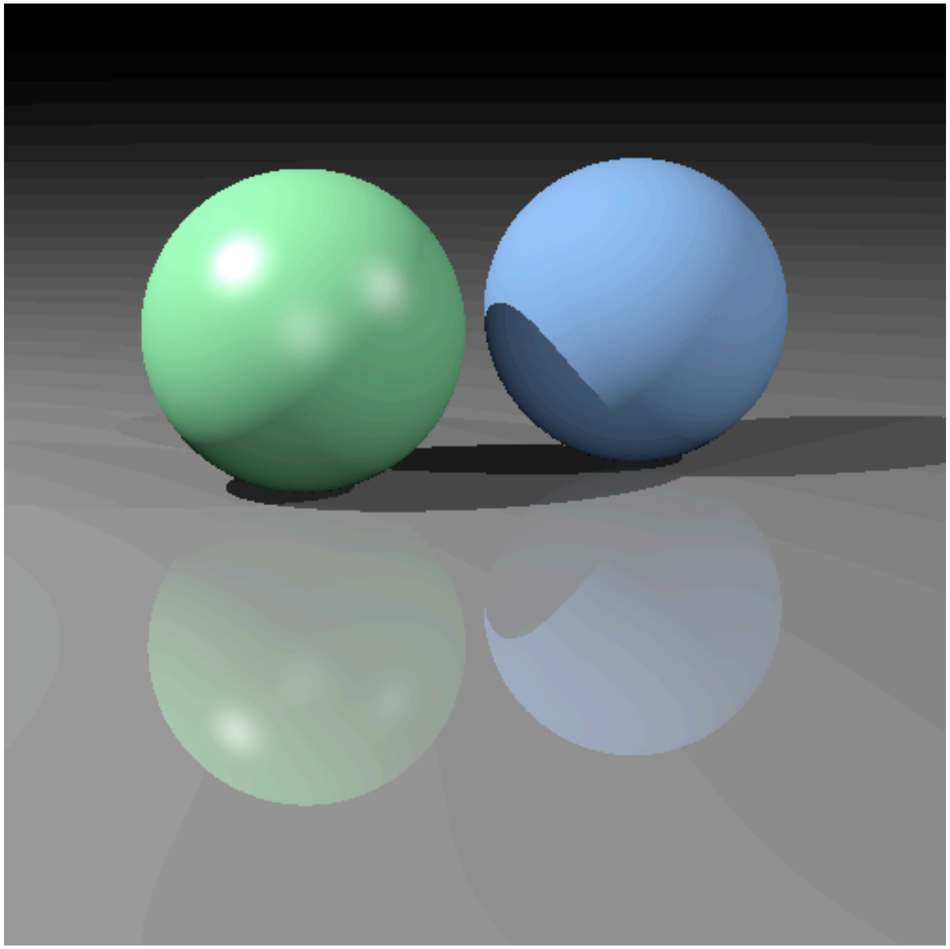
Mirror reflection

- Consider perfectly shiny surface
  - there isn't a highlight
  - instead there's a reflection of other objects
- Can render this using recursive ray tracing
  - to find out mirror reflection color, ask what color is seen from surface point in reflection direction
  - already computing reflection direction for Phong…
- "Glazed" surface has mirror reflection and diffuse

$$L = L_a + L_d + L_m$$

  - where L_m is evaluated by tracing a new ray

Diffuse + mirror reflection (glazed)



(glazed material on floor)