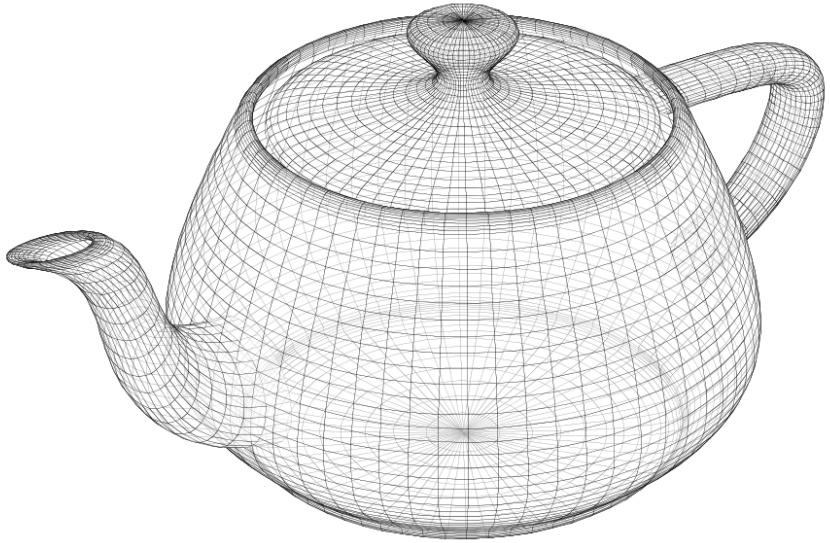


Phong Reflection Model

Production Computer Graphics

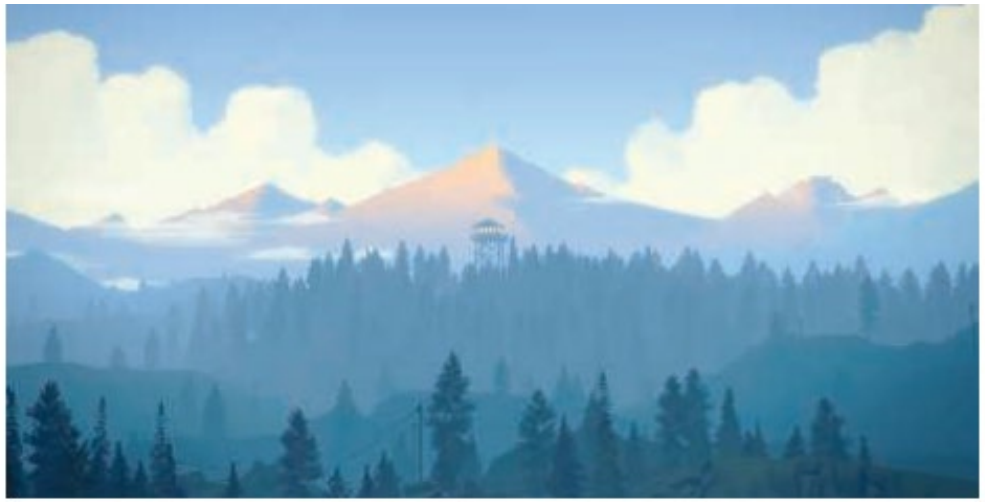
Eric Shaffer

ILLINOIS

Shading

The first step in determining the appearance of a rendered object is to choose a ***shading model*** to describe how the object's color should vary based on factors such as surface orientation, view direction, and lighting.

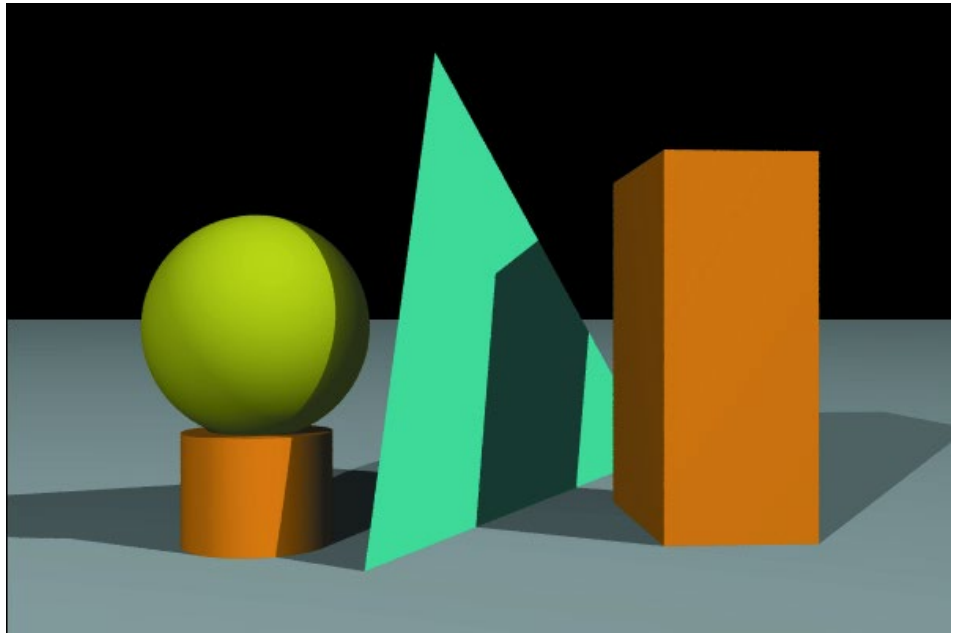
Akenine-Moeller, Tomas; Haines, Eric; Hoffman, Naty. ***Real-Time Rendering***, Fourth Edition



Phong Reflection

We model three types of light reflected by surfaces:

- Ambient (light that has bounced around a scene…environmental light)
- Specular (light reflected in a mirror-like fashion at surface)
- Diffuse (light scattered uniformly in all directions)



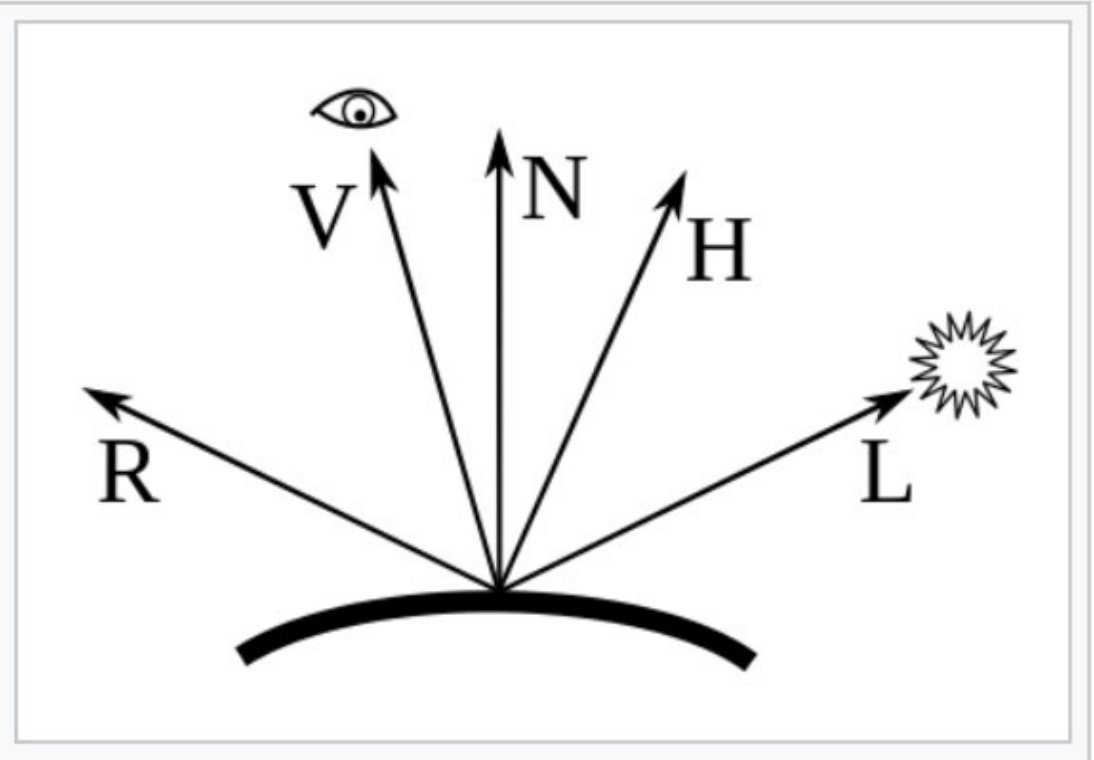
Here we can see diffuse reflection and maybe ambient.

How many lights are in the scene?

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

ILLINOIS

Phong Reflection Model



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

ILLINOIS

Ambient Light

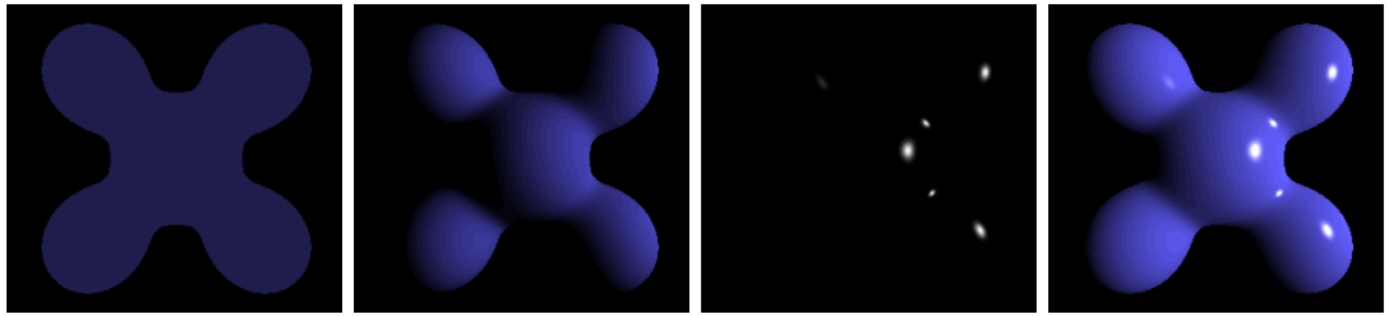
- Result of multiple interactions between light sources and surfaces
- Amount and color depend on the color of the light(s) and the material properties
- Add $k_a I_a$ to diffuse and specular terms

reflection

intensity of ambient light

Remember that k_i multiplications are component-wise multiplications of rgb values

$(k_r, k_g, k_b)(i_r, i_g, i_b) = (k_r i_r, k_g i_g, k_b i_b)$

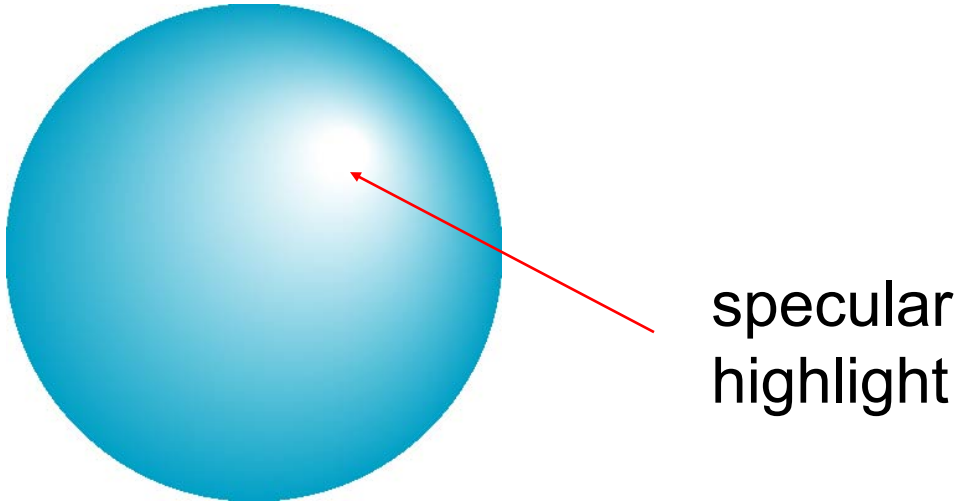


ILLINOIS

Specular and Diffuse Surfaces

- Most surfaces are neither ideal diffusers nor perfectly specular (ideal reflectors)

- Smooth surfaces show specular highlights
  - incoming light is reflected in directions concentrated close to the direction of a perfect reflection



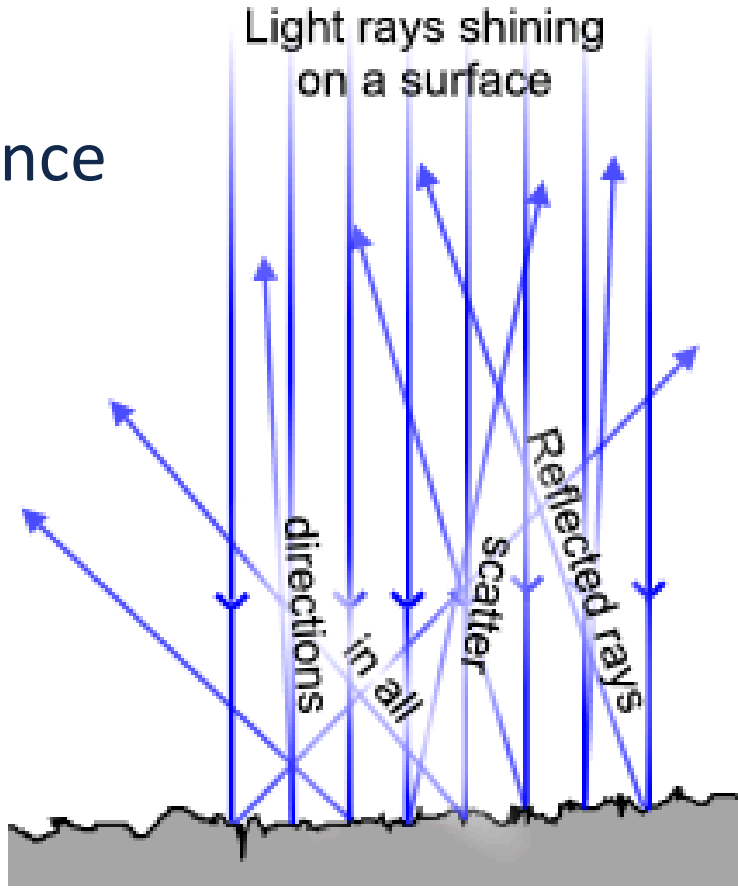
ILLINOIS

Modeling 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

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

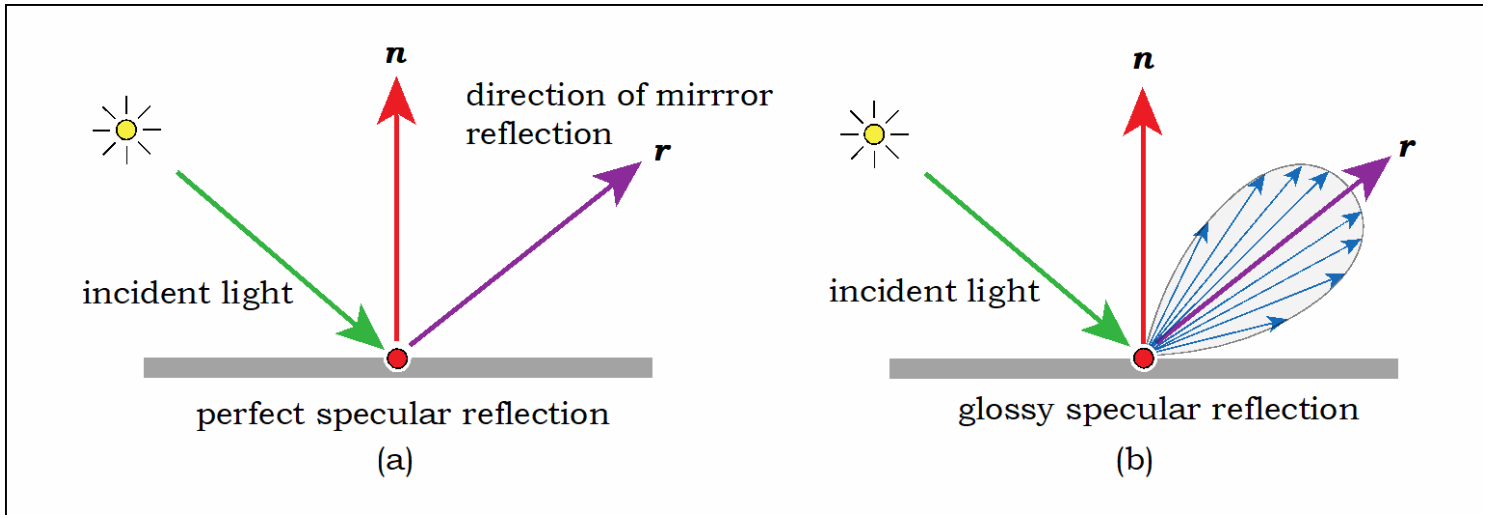
- Amount of reflected light also affected by k_d and i_d
  - Each is an rgb value with each channel in [0,1]

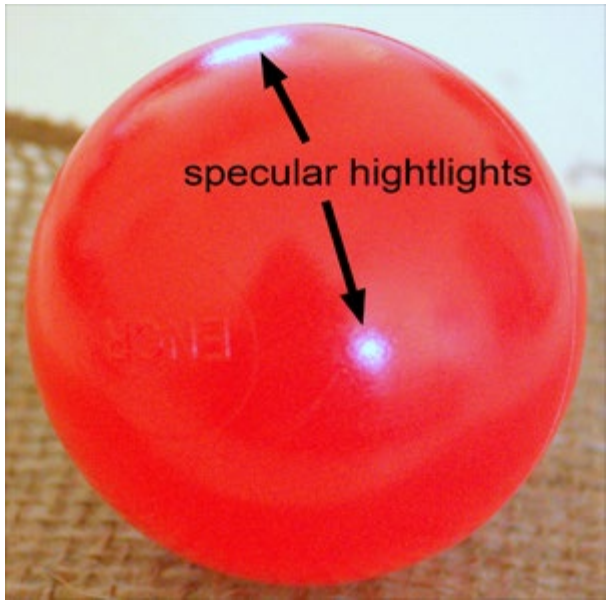


ILLINOIS

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

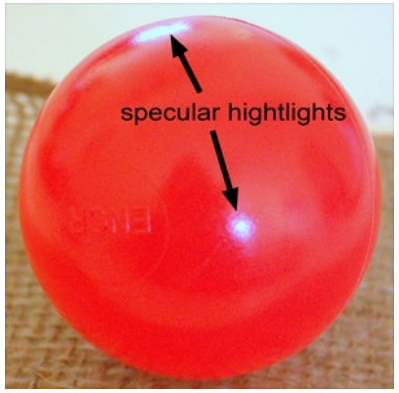




ILLINOIS

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



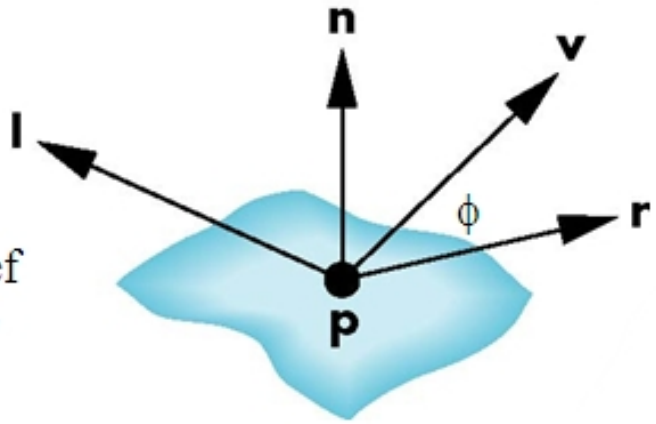
$$I_r \sim k_s I \cos^{\alpha}\phi$$

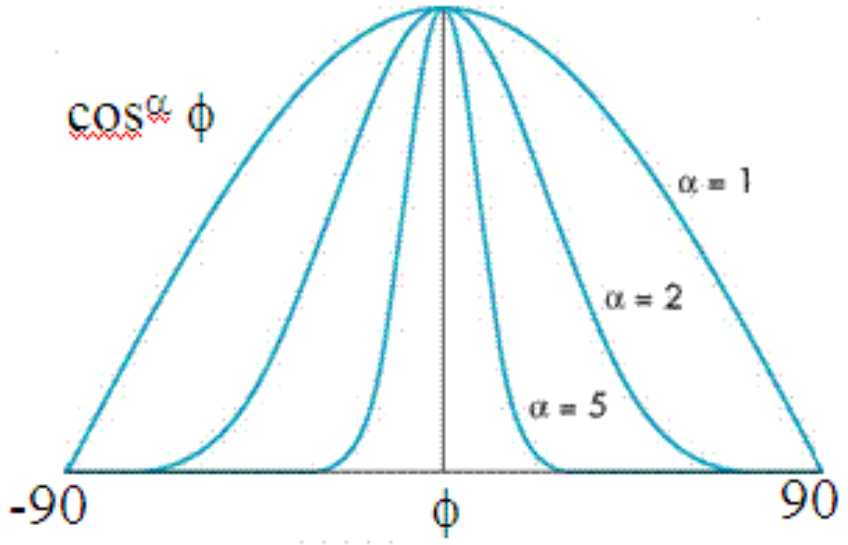
reflected intensity

absorption coef

incoming intensity

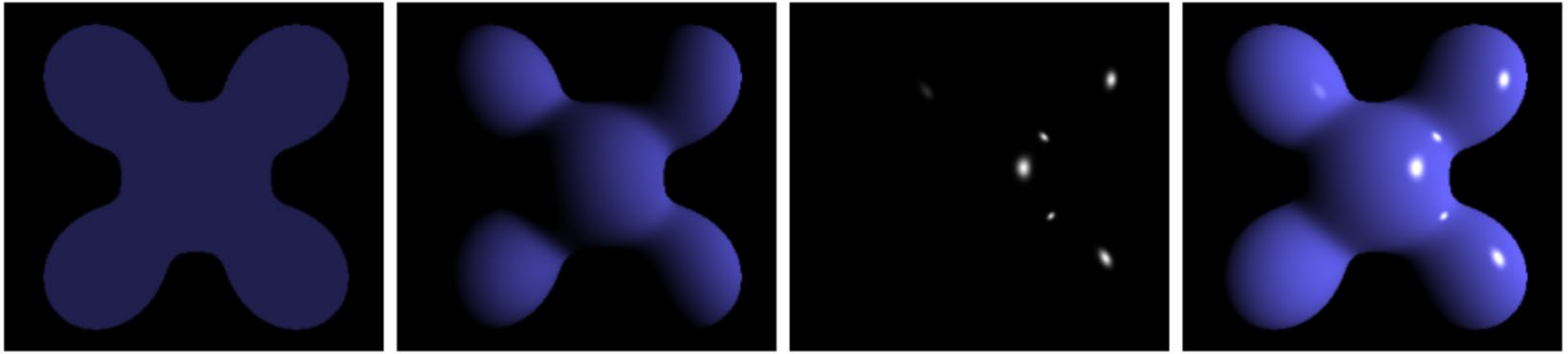
shininess coef





ILLINOIS

Phong Reflection Model

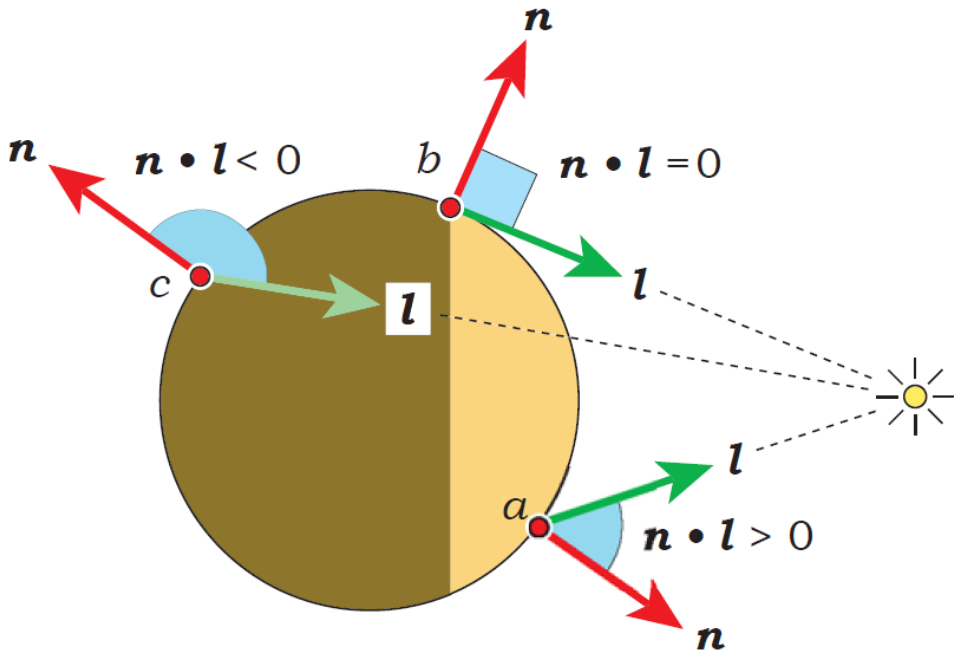


$$I_\mathrm{p} = k_\mathrm{a} i_\mathrm{a} + \sum_{m \in \text{ lights}} \left(k_\mathrm{d} (\hat{L}_m \cdot \hat{N}) i_{m,\mathrm{d}} + k_\mathrm{s} (\hat{R}_m \cdot \hat{V})^\alpha i_{m,\mathrm{s}} \right)$$

ILLINOIS

Shading vs. Shadows

You should clamp negative cosine values to zero

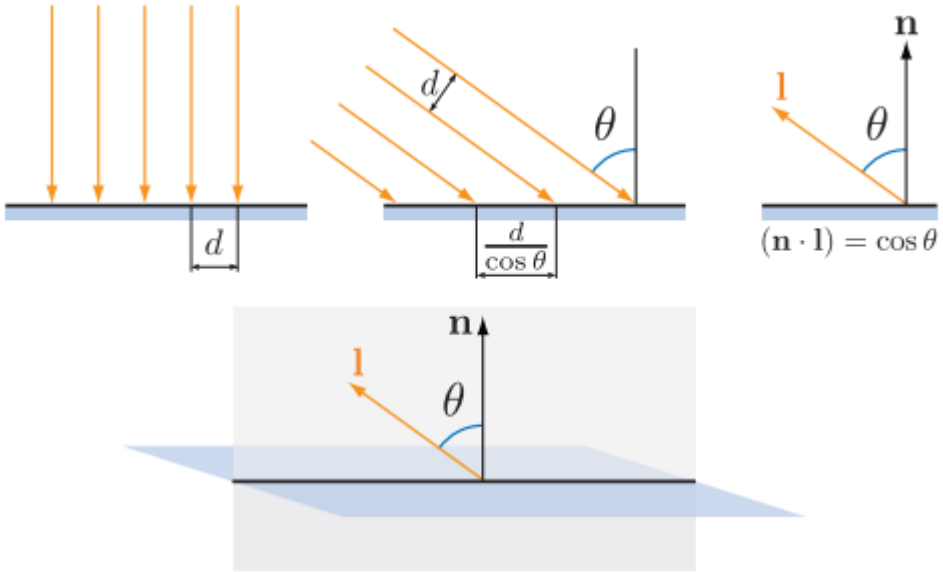


The darkness on the far side of the sphere is from the shading…NOT shadows…

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

ILLINOIS

Diffuse Reflection aka Lambertian Reflection



Model published by Johann Heinrich Lambert in 1760.

ILLINOIS