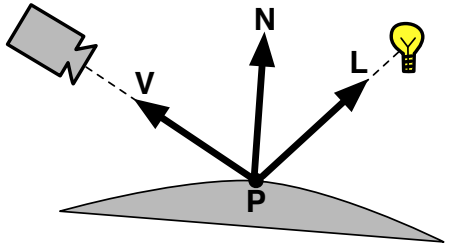
Phong Lighting

CS 442/452

September 18, 2012

Phong Illumination Model

- **local illumination model** : only direct interaction with light sources, surface, and camera considered (no shadows, reflections, *etc..*)



- **empirical model**: looks good (for certain materials and lights) but not based on physical model.
- Sums *ambient*, *diffuse*, and *specular* light reflected back to viewer:

$$I = I_{\text{ambient}} + I_{\text{diffuse}} + I_{\text{specular}}$$

- Model used in classic fixed OpenGL pipeline.

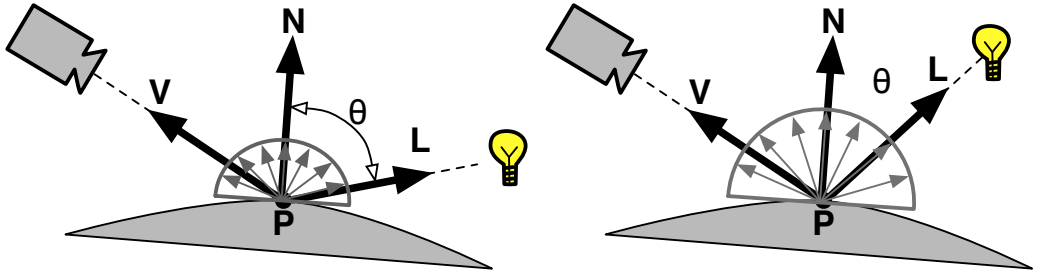
Ambient Light

- Light not tied to any single source.
- Uniformly bathes objects in the scene.
- Non-directional: the collective product of multiple reflections of light from the many surfaces present in the environment.

$$I_{\text{ambient}} = I_a \cdot k_a$$

- $0 \leq I_a \leq 1$: intensity of ambient light in scene.
- $0 \leq k_a \leq 1$: coefficient of ambient reflection (material surface property).

Diffuse Reflection

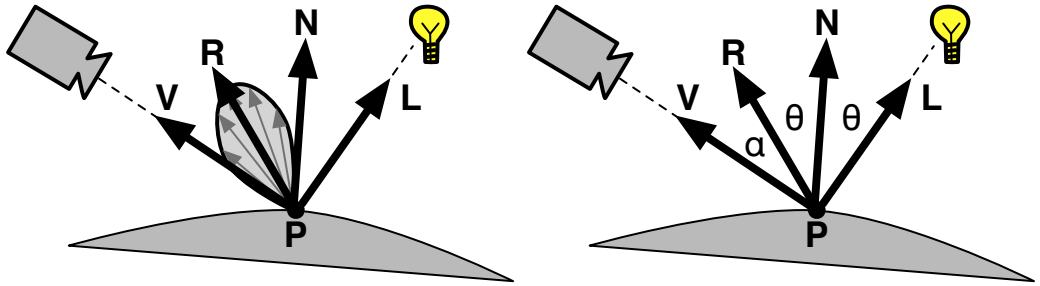


- Spreads light equally in all directions.
- Dull / matte surfaces (e.g. chalkboard)

$$\begin{aligned} I_{\text{diffuse}} &= I_p \cdot k_d \cdot \max(0, \cos\theta) \\ &= I_p \cdot k_d \cdot \max(0, \mathbf{N} \bullet \mathbf{L}) \end{aligned}$$

- Ip : intensity of point light source.
- k_d : material diffuse reflection coefficient.
- θ : angle between normal $\mathbf{N}$ and light direction $\mathbf{L}$.

Specular Reflection

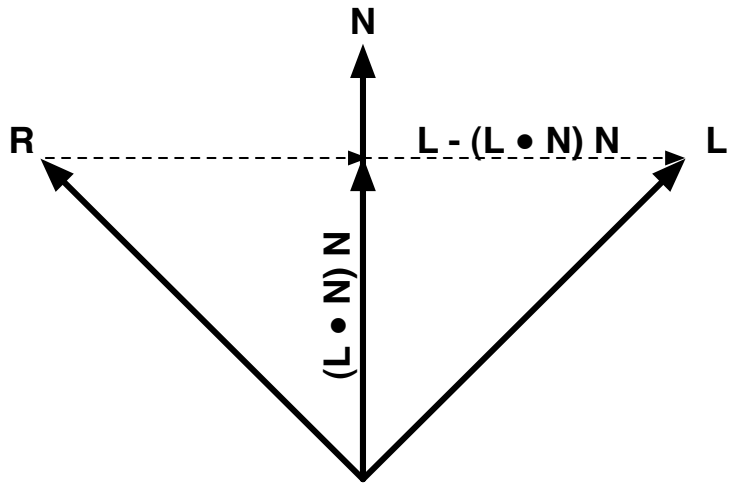


- Spreads light mostly in reflected direction $\mathbf{R}$.
- Shiny surfaces (e.g. mirrors, smooth plastic)

$$\begin{aligned} I_{\text{specular}} &= I_p \cdot k_s \cdot \max(0, \cos^n \alpha) \\ &= I_p \cdot k_s \cdot \max(0, (\mathbf{R} \bullet \mathbf{V})^n) \end{aligned}$$

- Ip : intensity of point light source.
- k_a : material specular reflection coefficient.
- α : angle between view $\mathbf{V}$ and reflected light $\mathbf{R}$.
- n : "shininess" exponent.

Computing the Reflection

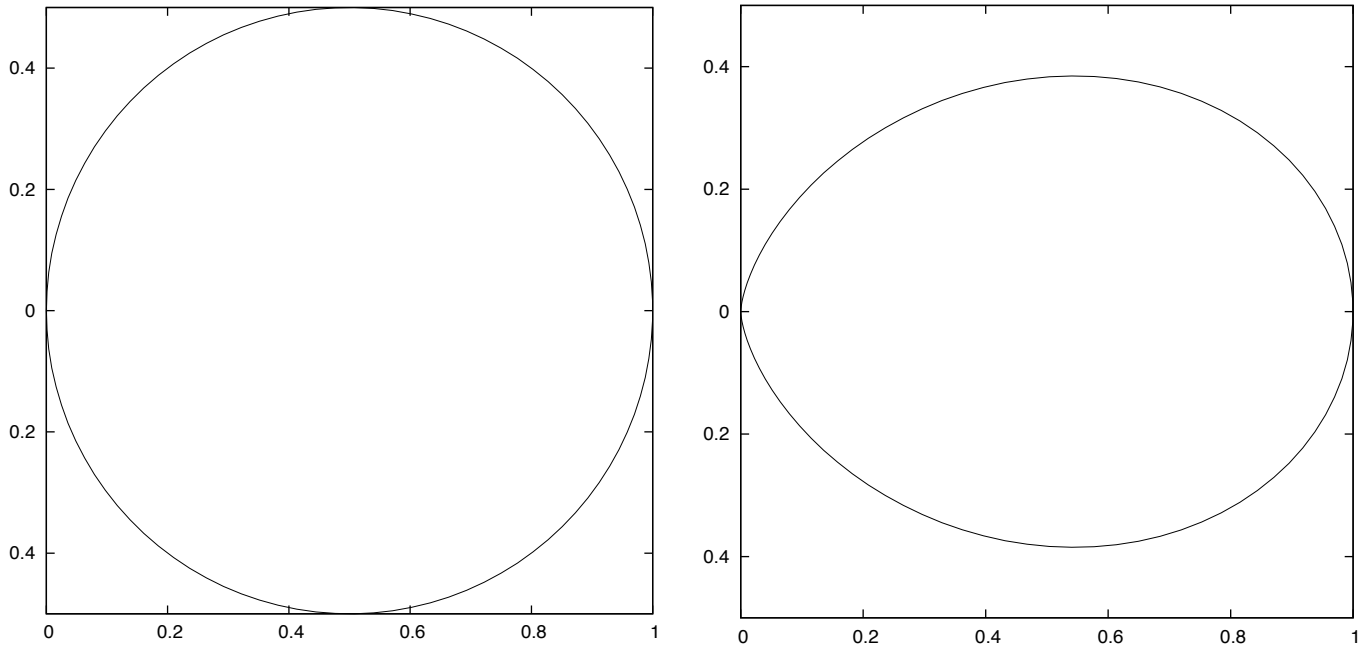


$$\mathbf{L} - \mathbf{R} = 2(\mathbf{L} - (\mathbf{L} \bullet \mathbf{N})\mathbf{N}$$

$$\mathbf{R} = 2(\mathbf{L} \bullet \mathbf{N})\mathbf{N} - \mathbf{L}$$

GLSL: `vec3 R = reflect(-L,N);`

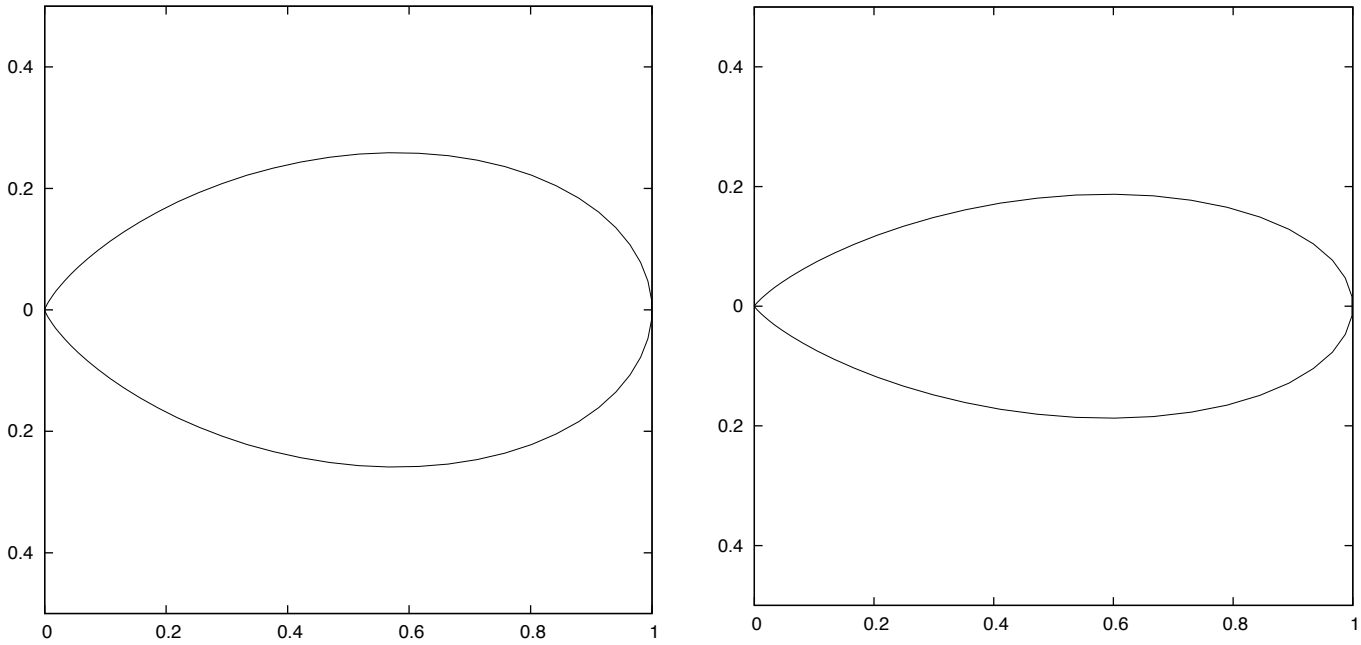
Cosine Lobes for $n = 1$ and $n = 2$



$\cos t$ (left) and $\cos^2 t$ (right) in polar coordinates

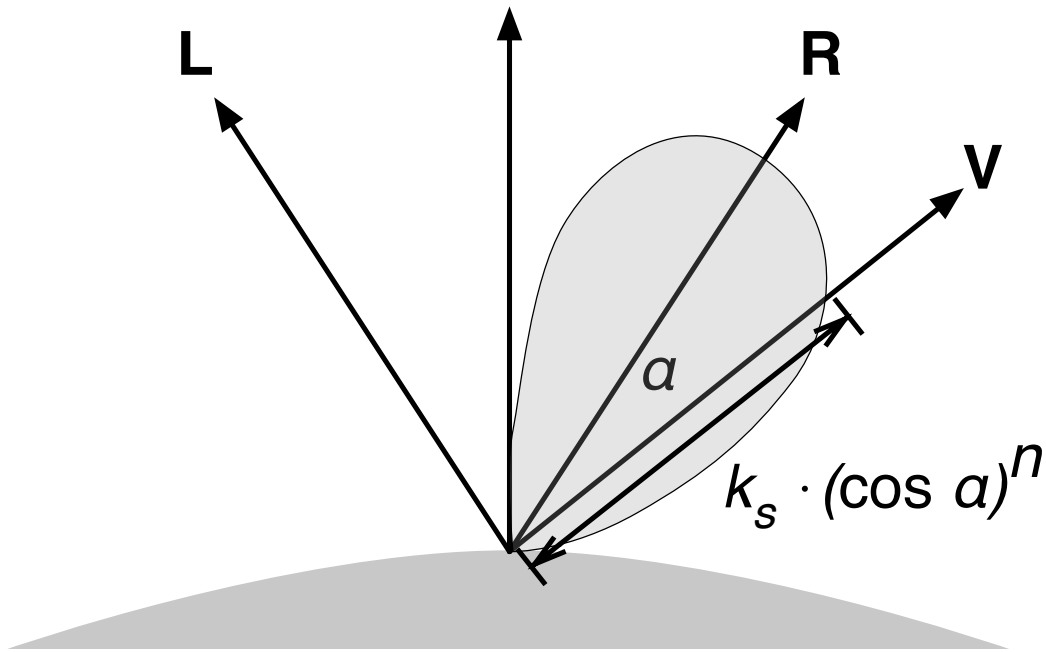
$-\pi/2 \leq t \leq \pi/2$

Cosine Lobes for $n = 5$ and $n = 10$



$\cos^5 t$ (left) and $\cos^{10} t$ (right)

Phong Specular Lobe



$$I = I_{\text{ambient}} + I_{\text{diffuse}} + I_{\text{specular}}$$

- Putting it together (I clamped to $[0, 1]$) :

$$I = k_a \cdot I_a + \begin{cases} 0 & \mathbf{N} \bullet \mathbf{L} \leq 0 \\ I_p \cdot (k_s \cdot \mathbf{N} \bullet \mathbf{L} + k_s \cdot \max(0, \mathbf{V} \bullet \mathbf{R})^n) & \mathbf{N} \bullet \mathbf{L} > 0 \end{cases}$$

- Multiple point light sources

$$I = I_{\text{ambient}} + \sum_p \left(I_{\text{diffuse}} + I_{\text{specular}} \right)$$

- Emissive surface

$$I = I_{\text{ambient}} + I_{\text{emmisive}} + \sum_p \left(I_{\text{diffuse}} + I_{\text{specular}} \right)$$

- Attenuation $A_p = 1/(k_c + k_l \cdot d + k_q \cdot d^2)$, $d =$ light dist.,

$$I = I_{\text{ambient}} + I_{\text{emmisive}} + \sum_p A_p \cdot \left(I_{\text{diffuse}} + I_{\text{specular}} \right)$$