

# Introduction to Lighting

## Background

Several terms for this topic:

- Lighting Model
- Illumination Model
- Shading Model

To achieve photo-realism requires multiple components. Some of these include:

- Accurate model (objects) descriptions; also known as materials.
  - Geometry, color, reflection, transparency, surface texture, emissive properties, etc.
- Accurate physical description of lighting
  - Point source, area light, color, position
- Accurate simulation of light transport, followed by rendering of the scene

For this class, we are going to focus on a lighting model that is loosely based in real-world physics. It isn't at the level needed for photo-realism, but it is pretty good.

## Types of Light/Material in a Scene

For the lighting model in this class, we will consider three sources of light and materials in a scene.

1. **Ambient** : Non-directional, uniform distribution illumination throughout a scene.
2. **Diffuse** (from a point source) : Light that is scattered equally in all directions on the surface of an object.
3. **Specular** (from a point source) : Light that is scattered non-uniformly about the normal to the surface of a model.

We are using a three channel, Red Green Blue, model for illumination and materials (reflection).

## Lighting Model

Light sources emit light intensity in each of the three channels.

$$\text{Ambient } L_a = \begin{bmatrix} L_{ar} \\ L_{ag} \\ L_{ab} \end{bmatrix} \quad \text{Diffuse } L_d = \begin{bmatrix} L_{dr} \\ L_{dg} \\ L_{db} \end{bmatrix} \quad \text{Specular } L_s = \begin{bmatrix} L_{sr} \\ L_{sg} \\ L_{sb} \end{bmatrix}$$

All values are in the range [0, 1]

## Material Model

$$\text{Ambient } k_a = \begin{bmatrix} k_{ar} \\ k_{ag} \\ k_{ab} \end{bmatrix} \quad \text{Diffuse } k_d = \begin{bmatrix} k_{dr} \\ k_{dg} \\ k_{db} \end{bmatrix} \quad \text{Specular } k_s = \begin{bmatrix} k_{sr} \\ k_{sg} \\ k_{sb} \end{bmatrix} \quad (\text{plus a shininess factor } p)$$

All values are in the range [0, 1]

## Reflection Model

### Ambient

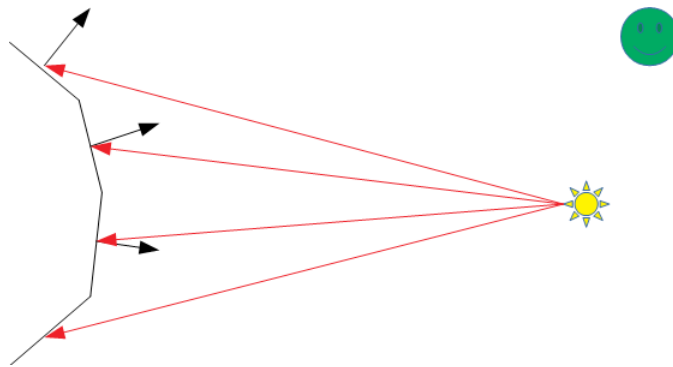
$$I_a = k_a L_a$$

## Diffuse

A perfectly diffuse reflector scatters light uniformly in all directions. As a result, the reflection from the surface appears the same to all viewers; the reflection is view-independent. The amount of reflected light, however, is dependent on the material, some of the light is absorbed.

### Lambert's Law of Cosines

Radiant energy from any small surface in any direction ( $\Theta_N$ ) relative to the surface normal is proportional to the  $\cos(\Theta_N)$ ; where  $\Theta_N$  is the angle between the normal of the surface and the direction of the light source. In other words, the light reflected from the surface is the same for any viewing direction.



We want the cos of the angle formed between the surface normal (N) and the vector from the point of interest on the surface to the light (L). We already have the surface normal provided by the geometry. The vector from the surface to the light is given by:

$L = P_L - P_g$  Where  $P_L$  is the position of the light and  $P_g$  is the surface point.

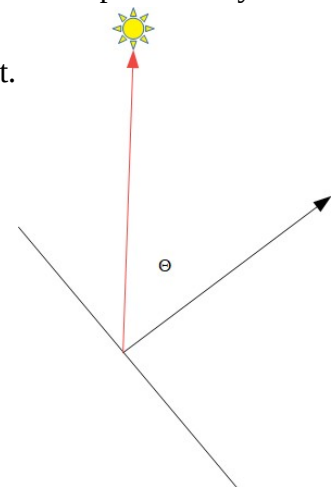
Both of these vectors need to be unit vectors.

The cos of the angle formed between these two vectors is the dot product:

$$\cos(\Theta) = N \cdot L$$

Therefore the reflected diffuse intensity is:

$$I_d = k_d L_d (N \cdot L)$$



### Gouraud Shading – Per Vertex Lighting

In Gouraud shading the intensities are computed at the triangle vertices and then interpolated over the surface.

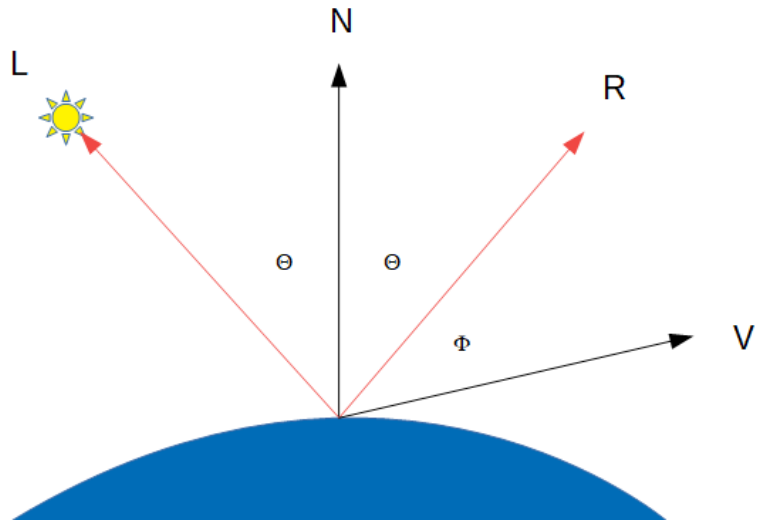
### Phong Shading – Per Pixel Lighting

In Phong shading the vertex normals are interpolated over the surface and the lighting is computed at each pixel (fragment).

## Specular

Diffuse shading results in surfaces that have a dull appearance to them, because the lighting is uniform across the surface. Shiny surfaces, on the other hand, such as an apple, metal, or my head, have a highlight (or bright spot) that is relative to the viewer. This is known as a **specular** reflection. This comes from the total or near-total reflection of the incident light around a particular region on the object's surface.

The specular reflection angle is the reflected angle of the light vector about the surface normal. Additionally, there is a shininess factor ( $n_s$ ) that describes how shiny or dull the surface is. This factor is a power function of the cos of the angle formed between the reflection vector and the vector to the viewer (eye/camera).



The reflection vector is computed as:

$$R = 2(N \cdot L)N - L \quad (\text{reflection vector of the light})$$

The viewing vector is computed as:

$$V = P_{eye} - P_v$$

Combining everything we know, the specular reflection is:

$$I_s = k_s L_s \cos(\Phi)^{n_s}$$

$$I_s = k_s L_s (V \cdot R)^{n_s}$$

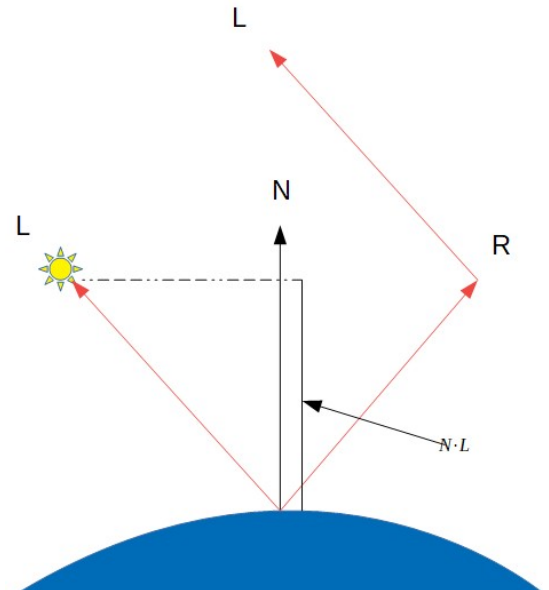
### Reflection Vector

The reflection vector can be computed in terms of L and N. The projection of L onto N is obtained with  $N \cdot L$ . Using that and considering the diagram, we have:

$$R + L = (2N \cdot L)N$$

After rearranging we get:

$$R = 2(N \cdot L)N - L$$



## Total Reflection

$$I = k_a L_a + k_d L_d (N \cdot L) + k_s L_s (V \cdot R)^{n_s}$$

- Computed for each color channel
- This is for a single light source. If more than one light source, accumulate the contribution from each light source.