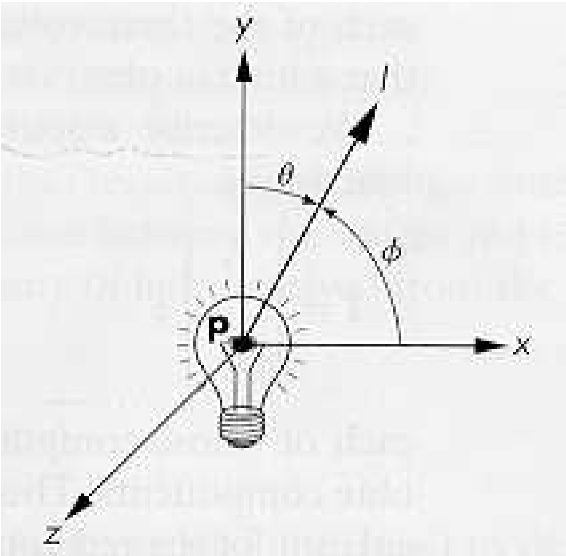
Light Sources

• **Ideal light sources**

- Each point on the surface can emit light that is characterized by

  * Direction of emission (θ, ϕ)

  * Intensity of energy emitted at each frequency λ



- Illumination function: $I(x, y, z, \theta, \phi, \lambda)$

- Total contribution from the source can be obtained by integrading over the surface of the source

- Correct model can be very complex

• **Modeling light sources**

- They have three components: *red*, *green*, and *blue*

Illumination function: $I = \begin{bmatrix} I_r \\ I_g \\ I_b \end{bmatrix}$

• Ambient light (or background color)

- A uniform illumination incident at every point in the scene

- A simple way to model the product of multiple reflections of light from many surfaces present in the environment

- <u>Ambient source:</u> $I = \begin{bmatrix} I_{ar} \\ I_{ag} \\ I_{ab} \end{bmatrix}$

- Different surfaces can reflect ambient light differently (based on the properties of the surface)

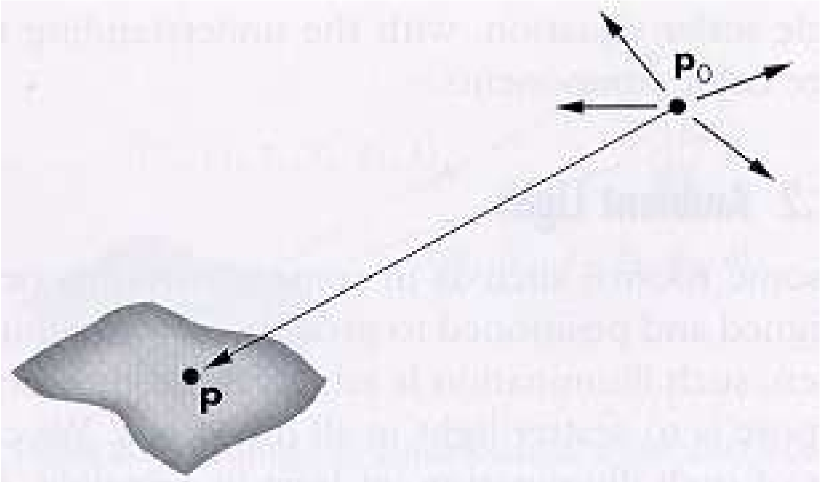
• Point sources

- Light is emitted equally in all directions

<u>Point source:</u> $I = \begin{bmatrix} I_r(p_0) \\ I_g(p_0) \\ I_b(p_0) \end{bmatrix}$

<u>Intensity of light received at point p:</u> $I(p, p_0) = \dfrac{1}{|p - p_0|^2} I(p_0)$

(instead of $d = |p - p_0|^2$, a term of the form $a + bd + cd^2$ is used in practice)

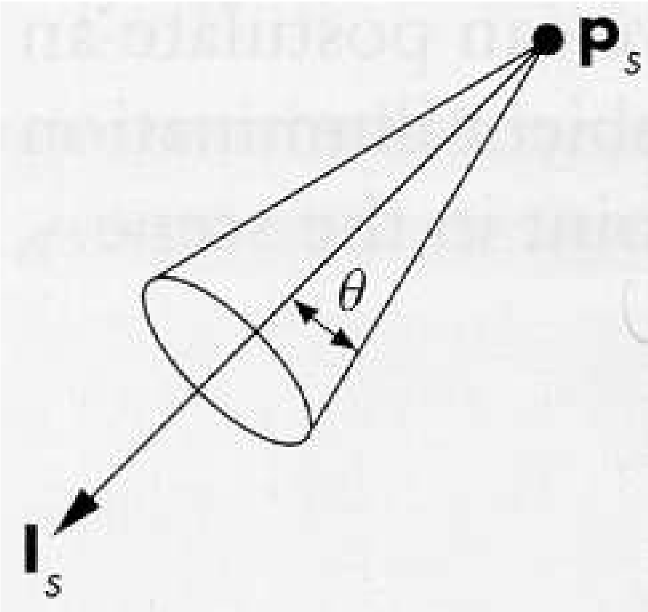


- Scenes rendered with only one source tend to have high contrast

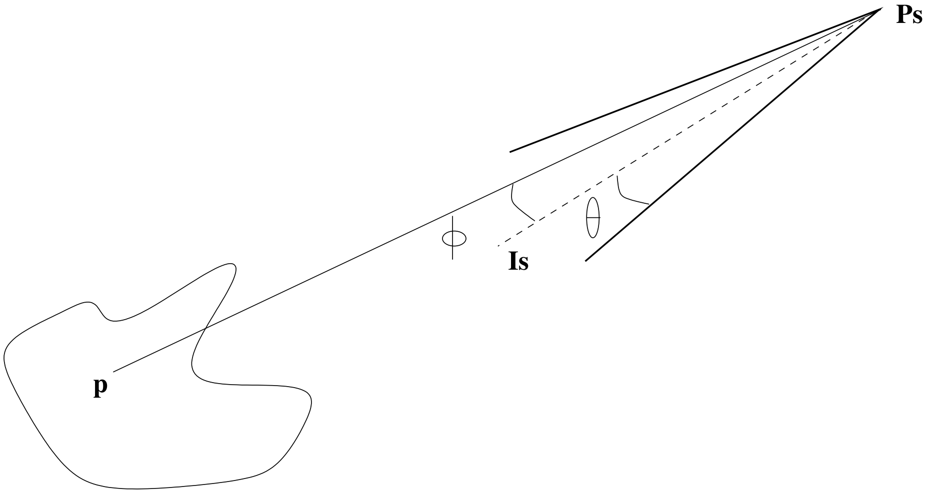
- If the light source is far from the surfaces in the scene, the intensity will be quite uniform

• **Spotlights**

- Light is emitted in a narrow range of directions only

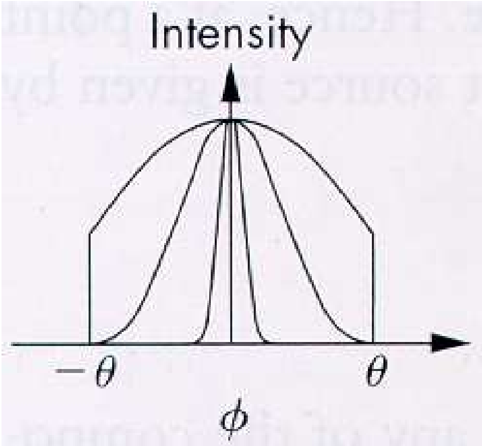


- The distribution of light within the cone varies with the angle ϕ



- The intensity is defined by:

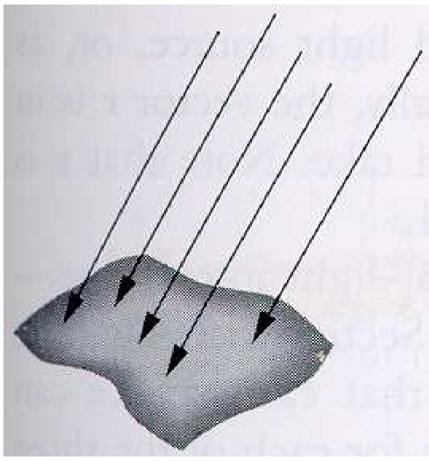
$$\cos^{e}(\phi) \text{ (if } \|s\| = \|l\| = 1, \ cos(\phi) = s.\,l)$$



• **Distant light sources**

- The direction of light is the same for every point in the scene

- Location of light source is at infinity



$$\text{point source: } \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}, \quad \text{parallel source: } \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix}$$

- Shading calculations are carried out more efficiently for parallel sources

Local Lighting Models

• General local lighting model

- Each **light source** has *ambient*, *diffuse* and *specular* terms

$$\begin{bmatrix} L_{ira} & L_{iga} & L_{iba} \\ L_{ird} & L_{igd} & L_{ibd} \\ L_{irs} & L_{igs} & L_{ibs} \end{bmatrix}$$

- **Reflection model** (material properties) contains *ambient*, *diffuse* and *specular* terms

$$\begin{bmatrix} R_{ira} & R_{iga} & R_{iba} \\ R_{ird} & R_{igd} & R_{ibd} \\ R_{irs} & R_{igs} & R_{ibs} \end{bmatrix}$$

- The color components specified for *lights* have different meaning than those specified for *materials*

    * For lights, the numbers correspond to the percentage of full intensity of each color

    * For materials, the numbers correspond to the reflected proportions of those colors

- Computing the color at a point p:

    * Computing the red diffuse term from light source i:

$$I_{ird} = R_{ird} L_{ird}$$

    * Computing the red intensity at point p from light source i:

$$I_{ir} = R_{ira} L_{ira} + R_{ird} L_{ird} + R_{irs} L_{irs}$$

    * Computing the red intensity from all the sources:

$$I_r = \sum_i I_{ir} + I_{ar} \ (I_{ar} \text{ is a global ambient term})$$

* The same computations must be repeated for I_g, I_b

* Computing the total intensity:

$$I = L_a R_a + L_d R_d + L_s R_s = I_a + I_d + I_s$$

• The Phong reflection model

- The following three types of material-light surface interactions are supported:

  * Ambient

  * Diffuse

  * Specular

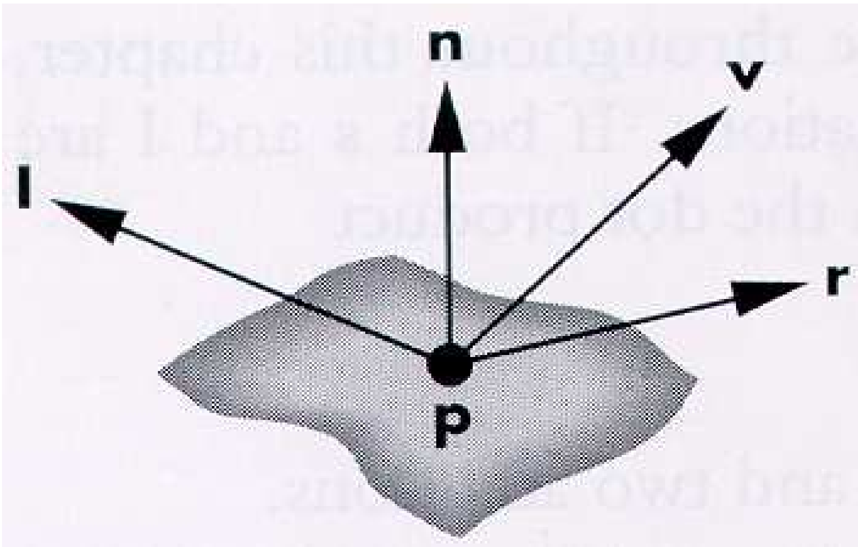
• Information used by Phong's model

n: normal at p

v: from p to the COP

l: from p to the light source

r: direction of -perfect- reflection



• Ambient reflection

- All points receive the same amount of light (L_a)

- The light reflected back is determined by a reflection coefficient (k_a)

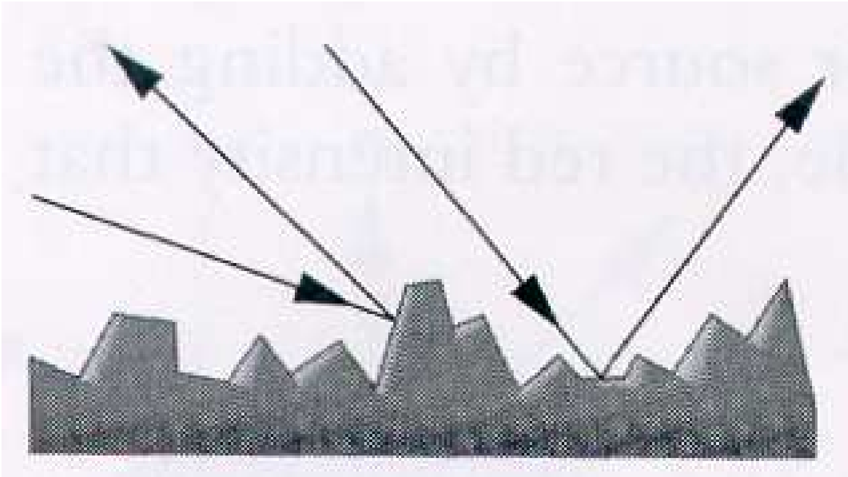
$$I_a = k_a L_a, \quad 0 \le k_a \le 1 \text{ (ambient reflection coefficient)}$$

(a surface can have three different ambient reflection coefficients: k_{ar}, k_{ag}, k_{ab})

• Diffuse reflection

- Produces surfaces which appear the same from every viewing direction (*Lambertian surfaces*)

- Diffuse reflections are characterized by rough surfaces



- The light received by a point depends on the angle θ between l and n

$$cos(\theta) = l.\,n, \text{ (if } \|l\| = \|n\| = 1)$$

- The light reflected back is determined by a reflection coefficient (k_d)

$$I_d = k_d (l.\,n) L_d, \quad 0 \le k_d \le 1 \text{ (diffuse reflection coefficient)}$$

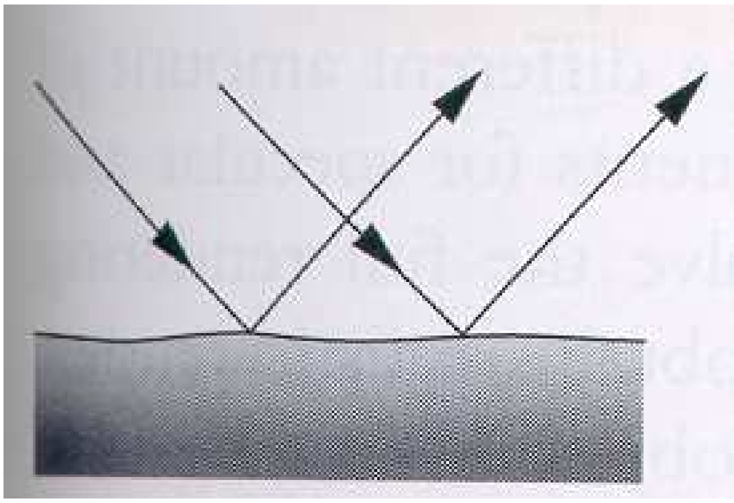
- Accounting for attenuation of light as the light travels from the source to an object

$$I_d = \frac{k_d}{a + bd + cd^2} (l.\,n) L_d \qquad (d\text{: distance})$$

• Specular reflection

- Produces shiny objects

- Specular reflections are characterized by smooth surfaces



- Light received by a point depends on the angle ϕ between r and v

$$cos(\phi) = r.\, v, \text{ (if } \|r\| = \|v\| = 1)$$

- The light reflected back is determined by a reflection coefficient (k_s)

$$I_s = k_s (r.\, v)^{\alpha} L_s,\ 0 \le k_s \le 1 \text{ (specular reflection coefficient)}$$

- α is a **shininess** coefficient

  Values $100 \le \alpha \le 500$ correspond to metallic surfaces

  As α->∞, we get a perfect mirror

  Values $\alpha < 100$ correspond to materials that show broad highlights

• Overal Phong model

$$I = I_a + I_d + I_s = \frac{1}{a + bd + cd^2} (k_d (l.\, n) L_d + k_s (r.\, v)^{\alpha} L_s) + k_a L_a$$