Visual Appearance (1): Illumination

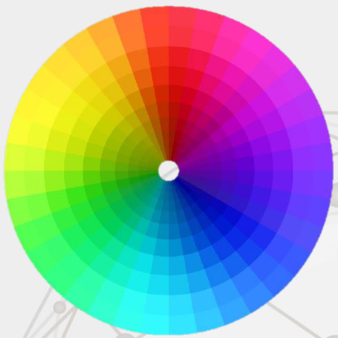
Lesson objectives

By the end of the module, you should be able to:

- Understand the three basic light sources
- Describe Phong illumination model
- Understand the effects of the three components of the model
- Apply Phong illumination model to compute color and intensity

1. Introduction

To create and display an image (or picture) using computer graphics, we need to compute the color and intensity of the light at each point in the content.



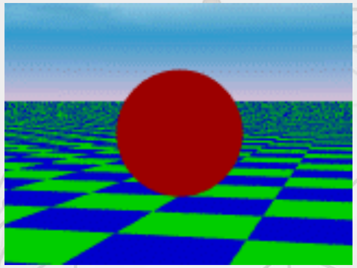
2. Light sources

- Ambient light source
- Directional light source
- Point light source

2.1 Ambient light source

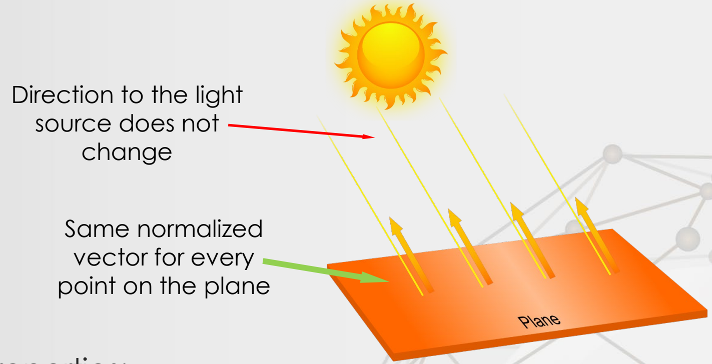
Problem: How to describe environment or background light?

- Environment or background light
  - Light is reflected from surrounding objects, not directly from light sources
  - Indirect illumination
- Property
  - No spatial or directional characteristics



2.2 Directional light source

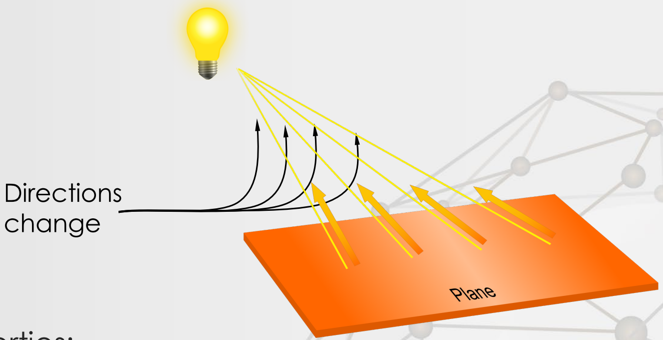
How to describe a light source that is very far away?



- Properties:
  - No point of origin
  - Same incident direction

2.3 Point light source

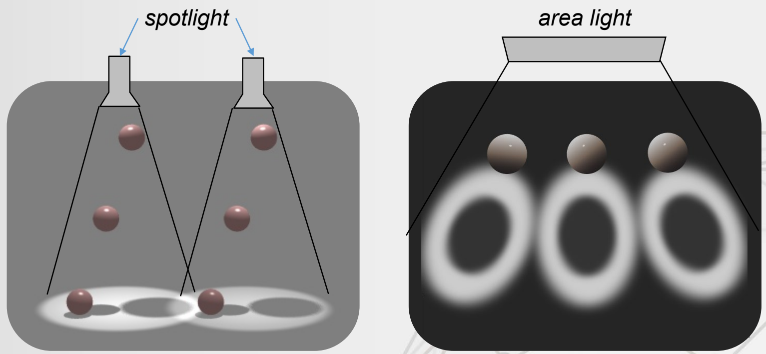
Problem: How to describe a light source whose dimension is very small compared to the environment?



- Properties:
  - All light rays radially diverge from a point

2.4 Something to think about

- Other light sources?



Click on the left or right illustrations above.

3. Empirical illumination model

Given the following information at a point P on a surface:

a. Normal vector N
b. Various surface parameters k_a, k_d, k_s, n
c. Lighting vector L and intensity I_{source}
d. Ambient light intensity I_a
e. Viewing vector V

You may click the tabs below for examples.

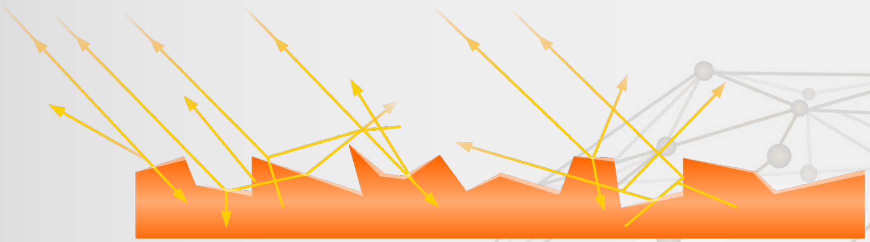
Normal vector | Lighting vector | Viewing vector

3.1 Ambient reflection

- Ambient light exists everywhere and reflects in all directions with equal intensity.
- How much is being reflected?
  - Determined by the surface properties; and
  - Independent from the surface's position and orientation.

3.2 Diffuse reflection

- Ideal diffuse (Lambertian) surfaces are very rough at the microscopic level.



3.3 Specular reflection

- Specular reflection accounts for the highlight in shiny, glossy surfaces, such as metals or plastics.

3.4 Total intensity

- Putting them all together:

$$I = \underbrace{k_a I_a}_{\text{Ambient reflection}} + \underbrace{k_d I_s \cos\theta}_{\text{Diffuse reflection}} + \underbrace{k_s I_s \cos^n \phi}_{\text{Specular reflection}}$$

- How about the situation where there are several light sources?

4. Phong illumination model computation

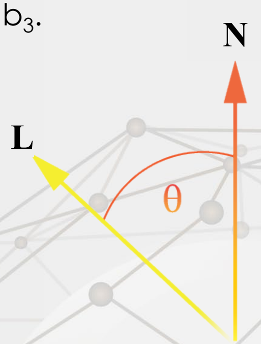
- How to perform actual computation with Phong illumination model?

$$I = k_a I_a + \sum_{\substack{\text{for each}\\ \text{light } s}} k_d I_s \cos\theta + \sum_{\substack{\text{for each}\\ \text{light } s}} k_s I_s \cos^n \phi$$

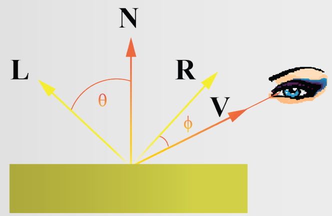
- The key is:
  - cosθ = ?
  - cosϕ = ?
- Our strategy is to use **vector calculation**.

Dot product of two vectors

- If N = [a_1 a_2 a_3], L = [b_1 b_2 b_3],
  then N•L = $a_1 \times b_1 + a_2 \times b_2 + a_3 \times b_3$.
- Geometric meaning:
  N•L = cosθ
  if N and L are unit vectors.



Computing reflections



- Refer to the left figure
  cosθ = N•L
  cosϕ = V•R
  where |L| = |N| = |V| = |R| = 1

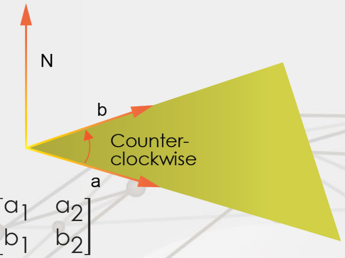
$$I = k_a I_a + \sum_{\substack{\text{for each}\\ \text{light } s}} k_d I_s \cos\theta + \sum_{\substack{\text{for each}\\ \text{light } s}} k_s I_s \cos^n \phi$$

$$\Downarrow$$

$$I = k_a I_a + \sum_{\substack{\text{for each}\\ \text{light } s}} k_d I_s (N \cdot L) + \sum_{\substack{\text{for each}\\ \text{light } s}} k_s I_s (V \cdot R)^n$$

How to compute normal?

- Polygonal surface
  - Use cross product of 2 vectors lying on a facet

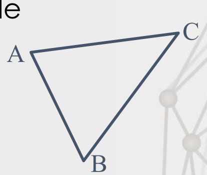


  - $\mathbf{a} = [a_1\ a_2\ a_3]$, $\mathbf{b} = [b_1\ b_2\ b_3]$
  - $N = \mathbf{a}\times\mathbf{b} = \det\begin{bmatrix} i & j & k \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{bmatrix}$

$$= i\det\begin{bmatrix} a_2 & a_3 \\ b_2 & b_3 \end{bmatrix} - j\det\begin{bmatrix} a_1 & a_3 \\ b_1 & b_3 \end{bmatrix} + k\det\begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix}$$

- Example: Triangle

$N=\overline{AB}\times\overline{AC}$



Summary

By now, you should be able to:

- Define and understand the three basic light sources:
  - Ambient light source
  - Directional light source
  - Point light source
- Describe Phong illumination model and understand the effects of its three components:
  - Ambient reflection
  - Diffuse reflection
  - Specular reflection
- Apply Phong illumination model to compute intensity/color:
  - Vectors L, N, V
  - Vector $R = 2\,(N \bullet L)\,N - L$