Illumination Models and Shading

- **Motivation**: In order to produce realistic images, we must simulate the appearance of surfaces under various lighting conditions.
- **Illumination Models**: Given the illumination incident at a point on a surface, what is reflected?

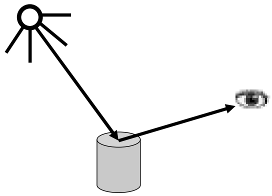


Image from http://radsite.lbl.gov/radiance/gallery/image/63b7.jpg

- The reflected light which is perceived is a combination of multiple light sources
- The surface properties also have a significant effect on the object color
- OpenGL simulates the lighting conditions with equations that:
- Approximate reality
- Are easy to implement
- Software renderers can calculate more realistic calculations

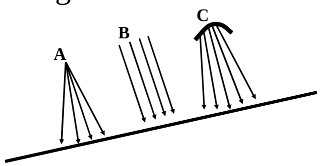
Illumination Model Parameters

- Lighting effects are described with models that consider the interaction of light sources with object surfaces.
- The factors determining the lighting effects are:
  - The light source parameters:
    - Positions.
    - Electromagnetic Spectrum.
    - Shape.
  - The surface parameters
    - Position.
    - Reflectance properties.
    - Position of near by surfaces.
  - The eye (camera) parameters
    - Position.
    - Sensor spectrum sensitivities.

- Illumination models is used to calculate the intensity of light that is reflected at a given point on a surface.
- Rendering methods use the intensity calculations from the illumination model to determine the light intensity at all pixels in the image, by possibly, considering light propagation between surfaces in the scene.

Lighthouse image from http://www.midwinter.com/~piaw/gallery/pigeonpointlighthouse.htm

Light Source Models



- **Point Source** (A): All light rays originate at a point and radially diverging.
  - A reasonable approximation for sources whose dimensions are small compared to the object size.
- **Parallel source** (B): Light rays are all parallel. May be modeled as a point source at infinity (the sun).
- **Distributed source** (C): All light rays originate at a finite area in space.
  - A nearby sources such as fluorescent light.

Illumination Models

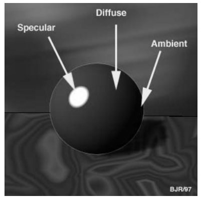
- Simplified and fast methods for calculating surfaces intensities.
- Calculations are based on optical properties of surfaces and the lighting conditions (no reflected sources nor shadows).
- Light sources are considered to be point sources.
- A reasonably good approximation for most scenes.

7

Phong Shading Model

1. ambient
2. diffuse
3. specular

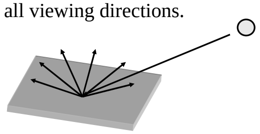
- The three components are computed independently and (weighted) summed



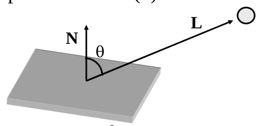
8

Diffuse Reflection

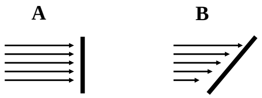
- Diffuse (Lambertian) surfaces are rough or grainy (like clay, soil, fabric).
- The surface appears equally bright from all viewing directions.



- The brightness at each point is proportional to cos(θ):



9



- This is because a surface (A) perpendicular to the light direction is more illuminated than a surface (B) at an oblique angle.
- The reflected intensity I_{diff} of any point on the surface is:

$$I_{diff}=K_d\ I_p\cos(\theta)=K_d\ I_p(N\cdot L)$$

I_p - the point light intensity.

$K_d \in [0,1]$ - the surface diffuse reflectivity.

N - the surface normal.

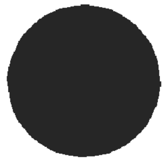
L - the light direction.

10

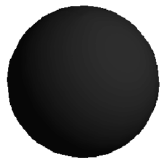
Ambient surface

Diffuse surface

11



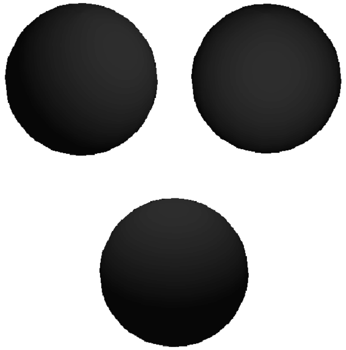
Ambient surface



Diffuse surface

12

Diffuse reflections from different light directions



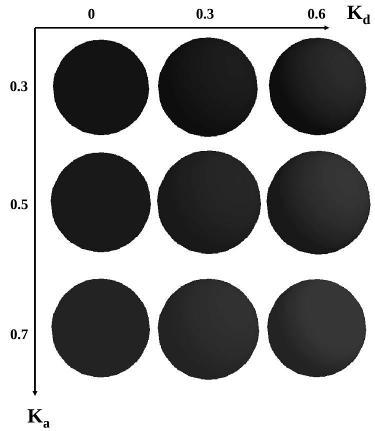
13

- Commonly, there are two types of light sources:
  - A background ambient light.
  - A point light source.
- The updated illumination equation is this case is:

$$I = I_{diff} + I_{amb} = K_d\, I_p\, N \cdot L + K_a\, I_a$$

- Note this is the model for one color and it should be duplicated for each channel: I^R, I^G, I^B .

14



15

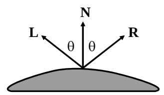
Specular light

- Specular light is also directional, but scatters in a preferred direction
- "Shiny materials" have a high specularity
- Matte materials have low specularity

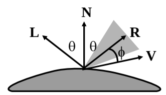
16

Specular Reflection

- Shiny and glossy surfaces (like metal, plastic) with *highlights*.
- Reflectance intensity changes with reflected angle.
- For an ideal specular surface (mirror) the light is reflected in only one direction - *R*.
- However, most objects are not ideal mirrors (glossy objects) and they reflect in the immediate vicinity of *R*.



Ideal specular surface



non-ideal specular surface

17

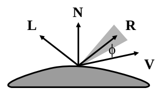
- **The Phong Model**:

  Reflected specular intensity falls off as some power of cos (ϕ):

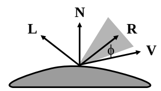
$$I_{spec} = K_s\, I_p \cos^n(\phi) = K_s\, I_p (R \cdot V)^n$$

K_s - the surface specular reflectivity.

n - specular-reflection parameter, determining the deviation from ideal specular surface (for mirror $n=\infty$).



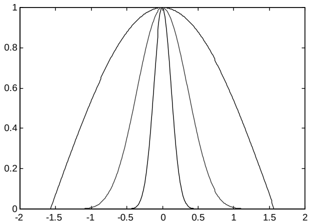
Shiny surface
Large n



Dull surface
Small n

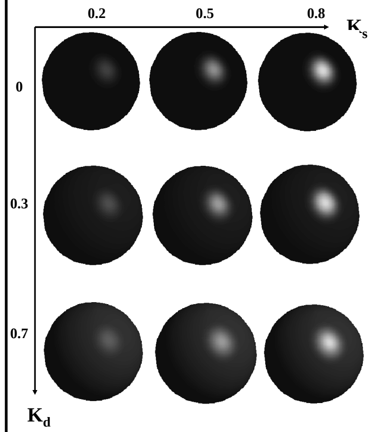
18

Plots of $\cos^n(\phi)$ for several specular parameter n.



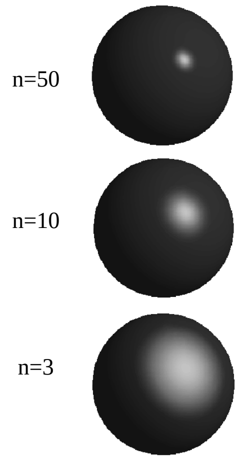
n=1
n=8
n=64

19



20

Several reflections with different specular parameters



22

Ambient Light

Ambient illumination is light that's been scattered so much by the environment that its direction is impossible to determine: it seems to come from all directions

23

Ambient Light

- Assume there is some non-directional light in the environment (background light).
- The amount of ambient light incident on each object is a constant for all surfaces and over all directions.
- The reflected intensity I_{amb} of any point on the surface is:

$$I_{amb} = K_a I_a$$

I_a - the ambient light intensity.

$K_a \in [0,1]$ - the surface ambient reflectivity.

- In principle I_a and K_a are functions of color, so we have I^R_{amb}, I^G_{amb}, I^B_{amb}

24

Examples: Ambient light reflections

- The updated illumination equation combined with diffuse reflection is:

$$I = I_{amb} + I_{diff} + I_{spec} = K_a I_a + I_p (K_d N \cdot L + K_s (R \cdot V)^n)$$

- If several light sources are placed in the scene:

$$I = I_{amb} + \Sigma_k (I^k_{diff} + I^k_{spec})$$

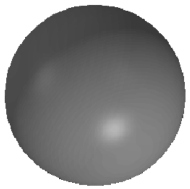
Commonly, there are two types of light sources:
A background ambient light.
A point light source.

Ambient surface

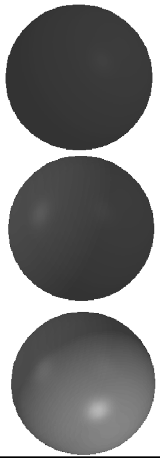
Diffuse surface

Diffuse + Specular

Composition of Light Sources



Composition of Light Sources

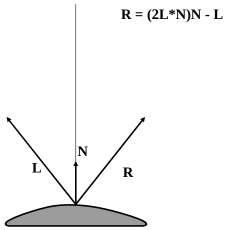


Summary

- Diffuse light comes from a single direction
  - Brighter if it strikes a surface directly
  - Scatters equally
- Specular light is also directional, but scatters in a preferred direction
  - "Shiny materials" have a high specularity
  - Matte materials have low specularity
- Ambient light compensate for not considering reflection from other surfaces

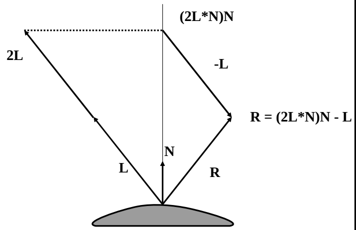
The Highlight Vector

First, let see how to compute the vector R, given L and N.



R is relatively expensive, and we can do better:

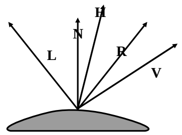
The Highlight Vector



The Highlight Vector

H = L+V

H*N ~~ V*R



Assuming L and V are constant per surface,
H is constant per surface for the given view.
Thus, we avoid computing R. The actual size of the angle can be compensated by the glossiness factor n.